The Geological History of the Vertebrates of Indiana

and

Their Position in the Ancient North American Fauna

By Roy L. Moodie

DIVISION OF GEOLOGY

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Restoration of one species of the ancient giant ground sloths (Mylodon harlani) as it probably looked in life. Under the heavy coat of stiff hair was a thick layer of fat containing a very great number of small bones which served as a protection against the attacks of carnivorous enemies. Although the mylodonts were doubtless sluggish and slow, yet it seems probable that a terrible wound could be made with their huge claws. The mylodonts were plant feeders, browsing off the leaves of shrubs and trees, as well as on succulent annuals. Representative specimens are found widely scattered throughout the United States. The painting, by John L. Ridgway, is based on abundant remains secured from the "Tar Pits" of the Rancho la Brea, at Los Angeles.

Courtesy of the Los Angeles Museum.

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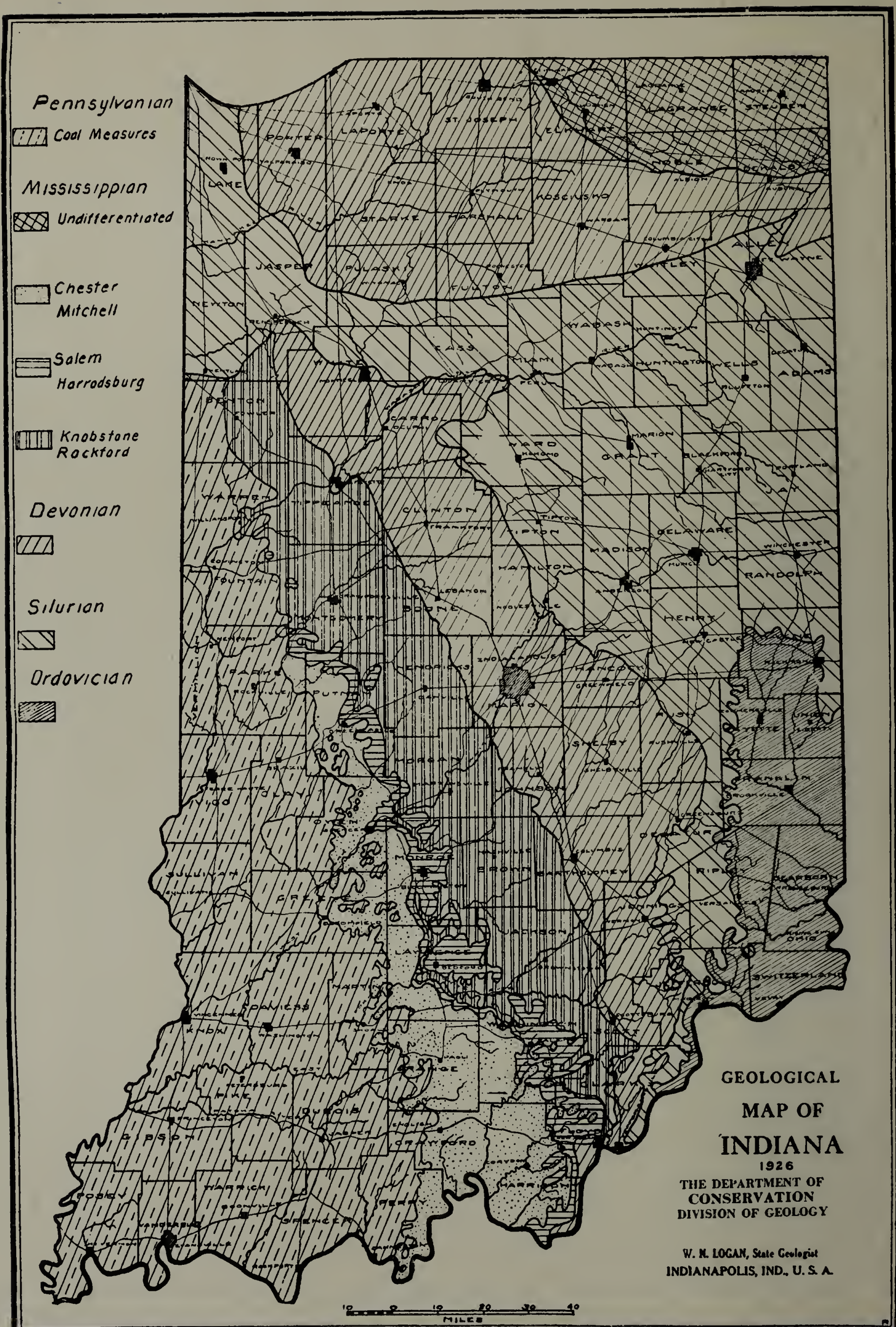
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THE DEPARTMENT OF
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DIVISION OF GEOLOGY
W. N. LOGAN, State Geologist
INDIANAPOLIS, IND., U. S. A.
MILES

Fig. 1.

INTRODUCTION

The following pages give, in a brief, non-technical form, accounts of the development of the vertebrate groups throughout all geological time, with local application of the relation of the fossil vertebrates as they have been discovered in the rocks of Indiana. This covers a period of discovery of more than three-quarters of a century. An important Devonian fish was described from Indiana in 1846 and this still remains an outstanding discovery in vertebrate paleontology.

Since the fossil vertebrates of Indiana only sketch here and there important paleontological events, we must go to the surrounding regions and even to distant countries to secure the evidences we need to tell the complete story. Modern political boundaries are of no importance in controlling the activities of Mother Nature. All paleontological knowledge has been scrutinized and that part pertaining to Indiana and its environs has been given prominence.

The fossil vertebrates which have been found in the rocks of Indiana are widely scattered. Some have been lost. Such is the condition in other states, and the institutions in Indiana itself possess only a small percentage of the materials which have been found within the borders of the state.

On account of the enormous and important aquatic vertebrate fauna in the Devonian a very full discussion has been given with illustrations of the varied groups of fishes, whose origins are uncertain, whose fates were either extinction, progression or continued unchanged existence.

There is little differentiation between the vertebrates of the Mississippian and the Pennsylvanian in the Indiana region, and the discussion here is given under the older group heading of Carboniferous. The discussion of the Carboniferous tetrapods is derived from discoveries in Illinois and in Ohio where in ancient swamps, preserved as beds of coal, the upland life of the Paleozoic is preserved. These four-legged creatures had made large progress by the close of the great Coal Period.

The Permian witnessed the close of the Paleozoic Period. On each side of the state of Indiana there are small pockets of Permian fossils: one in Pennsylvania and one in Illinois. Elsewhere the great, arid, Permian period left skeletons of a huge array of amphibians, reptiles, and a few fishes. For the first time true upland vertebrates existed.

The enormous stretches of time during the Mesozoic and the Cenozoic are entirely unrepresented in Indiana, and we know the vertebrates of these large, important epochs by discoveries made far outside, usually to the west and south, of the state limits. The Mesozoic witnessed the origin of birds and mammals, and the rapid growth of many large groups of reptiles, many of which became extinct either during the Mesozoic or at its close.

The Cenozoic, or Tertiary, is rightly called the Age of Mammals. During this time modern mammals developed from a host of groups which lost many elements through extinction. The story of mammal

life has been read chiefly from deposits in the western part of the country.

The great Pleistocene Period was full of interest, and Indiana possesses a pretentious record. The most important events, of course, were the successive invasions of great ice sheets, bringing enormous changes in the surface features and in the animal life. The period is usually regarded as having ended about 25,000 years ago: a very short time as geological events are usually regarded. The age witnessed the appearance of man, but this was not in America. It seems strange to find in Indiana undoubted evidences of elephants, tapirs, great ground sloths, and a beaver nine feet long, yet there they lived and left their remains in and around the great ice deposits. Why such creatures became extinct such a short time ago is an unsolved puzzle to paleontologists.

The Recent geological period, in which we are now living, witnessed the development and expansion of the human race. The period is believed to have already existed for 25,000 years, an infinitesimal fraction of time, as it is reckoned geologically. Fifty-five per cent of geological time had passed before life existed in any abundance, and of the 500,000,000 years the whole of the Age of Mammals and the Age of Man represent only a little more than four per cent.

THE RANGE OF VERTEBRATES IN GEOLOGICAL HISTORY

Animals having a spinal column of segmented parts composed of either cartilage or bone are known as *vertebrates*. The modern vertebrates are the fishes, amphibians, reptiles, birds and mammals. It is the history of these groups in geological time which we shall give in the following pages. The term *chordate* is used to designate those ancestral or primitive animals, related to the vertebrates, which have a vertebral axis or notochord in the adult condition, possessed by all vertebrates in their developmental stages. *Chordates* precede the *vertebrates* in geological history since their evidences are known in the Cambrian and in the Silurian and Devonian, during which latter period the true vertebrates, fishes to be sure, appeared in great numbers, known from a multitude of impressions, teeth, scales and bony parts. Fish-like animals have been described as occurring in the second period of geological history, the Ordovician, in Colorado, but the consensus of opinion now is that these rocks are of Devonian age.

A tabulation of the geological column will give the divisions of geological time, with the chief groups of vertebrates which are known to occur in each. The divisions of geological time are essential as names, but it must be kept in mind that geological history was, and is, a continual process. There were no divisions in time itself, but events differed from time to time in the various parts of the earth. While some periods end so abruptly that they seem to have been cut off with a knife, yet history was still being recorded elsewhere.

Eras	Periods	Life of the Period	Dominant Life
Psychozoic	Recent.	Human dominance. Animals of today.	Age of Man.
Cenozoic	Pleistocene or Glacial (Ice Age).	Periodic glaciation. Extinction of great mammals. Dawn of reason, art, industry.	Age of Mammals and Flowering Plants.
	Pliocene.	Man-ape changing into man.	
	Miocene.	Culmination of many groups of mammals.	
	Oligocene.	Rise of higher mammals, primates and modern birds.	
	Eocene.	Vanishing of archaic mammals.	

Eras	Periods	Life of the Period	Dominant Life
Mesozoic	Cretaceous.	Extinction of many groups of reptiles—dinosaurs, mosasaurs, plesiosaurs, pterosaurs.	Age of Reptiles.
	Comanchian.	Reptiles, birds, amphibians and fishes. Rise of flowering plants.	
	Jurassic.	Marine reptiles. Rise of toothed birds and flying reptiles.	
	Triassic.	Extinction of labyrinthodonts. First dinosaurs. Mammal-like reptiles. Mailed fishes.	
Paleozoic	Permian.	Reptiles. Amphibians.	Age of Amphibians and Ancient Fishes.
	Pennsylvanian, also called Upper Carboniferous.	First reptiles—Amphibians, Fishes.	
	Mississippian, also called Lower Carboniferous.	First amphibians. Sharks. Bony fishes.	
	Devonian.	First land vertebrates. Many groups of archaic fishes. Land animals—scorpions.	Age of Fishes.
	Silurian.	Chordates. Armored fish-like animals.	
	Ordovician.	No chordates known. Rise of land plants. Many invertebrates.	Age of the Invertebrates.
	Cambrian.	Traces of chordates. Many groups of invertebrates—trilobites, brachiopods, etc.	
Proterozoic.	Numerous periods.	No chordates known. Invertebrates. Plants.	
Archeozoic.		Unicellular plants. Algae.	

Geologists now believe that the earth has existed during at least 500,000,000 years. Of this time the Paleozoic represents 30%; the Mesozoic 11%; and the Cenozoic 4%. Fifty-five per cent of geological time is pre-Cambrian.

THE GEOLOGICAL HISTORY OF INDIANA

All geological time has been divided into six great eras, which, beginning at the bottom of the series, are called: Archeozoic, Proterozoic, Paleozoic, Mesozoic, Cenozoic, and Psychozoic. These have been given the following percentages as regards their relative duration, given in the same order—30%, 25%, 30%, 11%, 4%, and a fraction for the Psychozoic which is the Recent Period or Age of Man. Life has existed on earth probably all of this time, and the studies of Gruner* are important here.

Geological history is not recorded in surface formations of Indiana until well along in the Ordovician†, the second period of the Paleozoic. Thus all of the Archeozoic, Proterozoic and the Cambrian Period of the Paleozoic Era are unknown within the state except through the records of deep wells.‡ This is not of great importance in the history of the vertebrates because except for scant Cambrian evidence the vertebrates did not leave any records until the upper Silurian, and even then none are known from the rocks of Indiana. The recorded history of Silurian vertebrates has been found in eastern North America, Spitzbergen, Norway and western Europe.

The geological history of the vertebrates in Indiana begins with the Devonian arthrodire, *Macropetalichthys*, and discoveries in nearby regions give interesting accounts of the several groups of fish-like vertebrates which had developed so rapidly within the period. Early Devonian sedimentation is wanting in Indiana, and if found elsewhere will probably contain evidences of the forerunners of the later Devonian animals.

The Mississippian and the Pennsylvanian are well represented in Indiana, and these rocks contain evidences of marine, fresh water, and upland life in the vicinity of the state. The older term Carboniferous includes these two divisions, and the discussion of the vertebrates is given as of the Carboniferous, since we are so far unable to differentiate the vertebrates of these periods. The Coal Measures Amphibians in Illinois and in Ohio are especially well preserved and show a high degree of development.

The rich vertebrate fauna of the Permian period, which witnessed the close of the Paleozoic, is unknown in Indiana.

The entire extent of the long and important eras, the Mesozoic and the Cenozoic, are wanting in Indiana. We have tried to follow the history of vertebrate development from records discovered elsewhere.

The geological records of the Pleistocene, the Great Ice Age, are important and complete. There is a notable record of vertebrate life and we shall compare it with paleontological records elsewhere. Nearly the entire surface of the state was subjected to glacial action and this had an important bearing on vertebrate history.

* Gruner, John W. 1923. Algae, believed to be Archean. Journ. Geol., xxxi, 146-148, illus. 1925. Discovery of Life in the Archean. Jour. Geol., xxxiii, 151-152, illus.

† Cumings, E. R. 1922. Nomenclature and Description of the geological Formations of Indiana. Part IV of Handbook of Indiana Geology, pp. 403-570, illus. Publication No. 21, Dept. of Conservation, State of Indiana.

‡ Logan, W. N. 1926. Geology of the Deep Wells of Indiana, 540 pp. 2 illust. Publication No. 55, Dept. of Conservation, State of Indiana.

THE PROBLEM OF VERTEBRATE ORIGINS

The origin of the vertebrates, we may as well say at once, is still an unsolved problem, but the question is of such great importance that eager inquiry continues to bring forth new facts, new theories and new lines of approach. We believe that in time the problem will be solved, but at present all we can say is that the new method of approach has so far not been successful.

Anton Dohrn, believing that the simple vertebrates arose from some annelid group, sought for years the solution of the problem in morphological studies among animals which he thought might yield light on the problem. His results were unsatisfactory and his researches now have only an historical interest.

Gaskell took up the problem from the standpoint of function and structure and concluded that the ancestral vertebrate was a segmented anthropod. His results lacked the proof necessary to acceptance and his studies are now only of historical interest.

Patten took up the problem from the dual standpoint of development and structure and concluded that the ancestral chordate arose from some arachnoid group. However, it is now not generally thought that the vertebrates arose from *any* known invertebrate.

The general aspects of the problem have been changed in recent years by the discovery of possible chordate remains in the Cambrian, and by great discoveries of primitive chordates, in relative abundance, in rocks of Upper Silurian age in various parts of the world, so that at present the problem of the origin of the vertebrates is strictly a paleontological one involving the interpretation of the ancient fossils themselves.

A LIST OF RECENT STUDIES DEALING WITH VERTEBRATE ORIGINS

(1) Kiaer, J. 1928. The structure of the mouth of the oldest known vertebrates, pteraspids and cephalaspids. Palaeobiologica, Bd. 1, pp. 117-134, illus.

(2) ——— 1924. The Downtonian Fauna of Norway. I. Anaspida. Videnskapsselskapets Skrifter. I. Mat. natur. Klasse, No. 6. pp. 1-139, illus.

(3) Simpson, G. G. 1926. New reconstruction of Lasanius. Bull. Geol. Soc. Amer., 37, pp. 397-402, illus.

(4) Stensiö, Eric A: son. 1927. The Downtonian and Devonian Vertebrates of Spitsbergen. Two volumes, illus. Oslo.

(5) Stetson, Henry C. 1927. Lasanius and the problem of vertebrate origin. J. Geol., xxxv, pp. 247-263, illus.

(6) ——— 1928. A restoration of the anaspid Birkenia elegans Traquair. Ibid., xxxvi, pp. 458-470, illus.

(7) ——— 1928. A new American Thelodus. Amer. J. Sci., xvi, pp. 221-231, illus.

METHODS OF COLLECTING FOSSIL VERTEBRATES

The size and complexity of fossil vertebrates introduces new methods for their recovery, preservation, and their exhibition in geological museums. Paleozoic marine vertebrates are largely recorded by teeth and spines and are brought to light in connection with geological field work, as incidents in stone quarrying operations, and by deliberate search. The specimen is secured within a piece of rock, and carried to the laboratory for further exposure, or removal, by the use of sharp-pointed tools, much as invertebrate fossils are handled.

Fig. 2. The flat, light colored concretion at the point of the pick, contained a pressed cladoselachian shark about four feet in length, now preserved in the Cleveland, Ohio, Museum. In order to secure the specimen considerable excavation in the hard Cleveland shale (Devonian) was necessary. This exposure is on Big Creek, near the edge of the city of Cleveland, Ohio. After Hyde.

Many times vertebrate remains are enclosed within concretions or smaller nodules. Sometimes, as at the Mazon Creek beds in Illinois, the enclosed fossil, whether fish, amphibian or insect, forms a plane of weakness along which the nodule splits, following a well-directed blow or the action of frost. The cladoselachians within the large, heavy concretions in the Cleveland shale of Ohio require somewhat different treatment, and careful manipulation in the laboratory is needed to expose the inclosed shark or arthrodire.

If a larger animal is preserved in the rocks the procedure is to first uncover the entire remains, often a laborious task of digging, then to support the friable parts with pasted cloth, plaster or cement, and

Fig. 3. Pleistocene elephant bones exposed in the bottom of a pit. If the bones are firm and well preserved they can be lifted out bodily, but in case they are friable, care must be taken to avoid injury to the specimens. They must be hardened and treated with shellac or gum and supported by sticks of wood fastened with bandages.

ship to the laboratory with a large amount of matrix, as the mother rock is called.

If a large bone is greatly fragmented and preserved in loose material, the pieces are carefully wrapped to protect the edges, the parts numbered in a diagram which guides the matching of the broken parts in the museum laboratory.

Indian burials may be collected entire by the use of proper hardening of the soil, and crating the entire grave.

Fig. 4. A heap of bones of the great ground sloth shown in the Frontispiece, exposed in a pit in Pleistocene deposits. These bones were firm and could be readily lifted out.

THE PRE-DEVONIAN VERTEBRATES OF NORTH AMERICA

Scant evidences of the presence of chordates are known from Cambrian rocks of Vermont* and similar problematical fossils† have been discovered by Cobbold in the lower Cambrian rocks of Comley in Shropshire, England. *Eoichthys howelli* is the name proposed for the oldest known American chordate. The size of the single plate in the Cambrian shale is 3 mm. in length by 2 mm. in width. The ellipsoid plate is truncate at one end, and it is ornamented with smooth conical tubercles. If it really is a chordate the plate represents one of the polygonal head scales of an unknown Ostracoderm. Such a discovery is to be expected since recent discoveries in the Silurian show many fish-like chordates to have been fully developed, though small, indicating a long preceding period of growth. One conclusion we may draw from such scant indications is that, in all probability, the chordate ancestral forms were pre-Cambrian in age. We must search in the deposits of the Proterozoic for the ancestors of the vertebrates. The group did not arise from any known group of invertebrates.

One is impressed with the uniformly small size of the pre-Devonian chordates. It has been suggested that this size is due to the scarcity of plant food, which is the basic nutrition. All of the pre-Devonian chordates were small, none of them exceeding a few inches in length. They are believed to have been inhabitants of fresh-water, since the seas were made dangerous by the host of invertebrates, cephalopods, trilobites and others. In the shallow, brackish estuaries the early chordates survived with difficulty, since this was the habitat of the Eurypterids, giant scorpion-like monsters, attaining a length of many feet, with a rapacious appetite needing many primitive chordates to satisfy. The early chordates were better off in fresh water, where they had fewer enemies.

Following the Cambrian period came the Ordovician, in whose rocks students have announced that they found fish-like remains in several places in the western states. It is the consensus of opinion now, however, that these fish-like creatures are in reality of Devonian age, and chordates are unknown in Ordovician rocks.

Not until we get well along into the upper Silurian do we find further traces of chordate life. Bryant‡ announced the discovery in the upper Silurian, in the Bloomsburg shale, of Pennsylvania and in the Guymard Quartzite beds near Otisville, New York, of parts of primitive, fish-like chordates (Figure 5), representing the ostracoderms, of which only the head shields are known. These remains were associated in the rocks with fossils of marine habitat such as the brachiopods, trilobites and eurypterids, which casts doubt upon the restricted fresh-water

* Bryant, William L. 1926. Evidence of the presence of chordates in the Cambrian. 15th biennial Rept., Vermont State Geologist, pp. 125-126, fig. 1.

† Letter from William L. Bryant, date January 18, 1928.

‡ Bryant, William L. 1926. On the Structure of Palaeaspis and on the occurrence in the United States of fossil fishes belonging to the family Pteraspidae. Proc. Amer. Philos. Soc., lxv, 256-271, illus.

Fig. 5. A restoration of a Silurian chordate, *Palaeaspis bitruncata* Claypole, based on material from the Bloomsburg shale, Perry County, Pa. Related forms are known from New York. The tail is hypothetical. Note the absence of fins. Specimens preserved in Princeton University and in the New York State Museum. After Bryant.

habitat of these early chordates. These ancient Silurian chordates were only a few inches long. Bryant believes that they had migrated some thousands of miles from their ancestral home in northwestern Europe. This migration, of course, took hundreds of thousands of years. A migration rate of a few feet a century would be adequate to account for their presence in such widely removed places as Spitsbergen and Pennsylvania.

More recently Stetson* has described the occurrence of another primitive chordate, *Thelodus*, related to other forms of the European family Coelolepidae, in upper Silurian rocks of New Brunswick, the beds being regarded as Downtonian. The anterior part of the body in *Thelodus* was covered with hard small scales. The animals probably had no true jaws, and hence are included in the group of Agnatha,

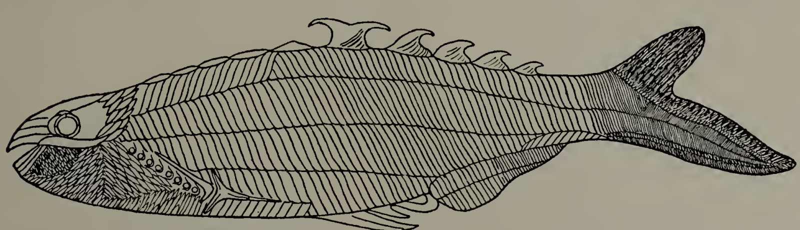

Fig. 6. A restoration of an anaspid, *Birkenia elegans* Traquair, an early primitive, fish-like chordate, found in the Downtonian (Upper Silurian) of Lanarkshire, Scotland. After Stetson.

showing some relationship with the primitive sharks and the Ostracoderms. In length the primitive chordates, the Coelolepidae, were more than twelve inches. Orbits have not been defined in this chordate, and other sensory organs are unknown.

In order to understand better the real nature of the pre-Devonian chordates as a whole, it will be profitable to give here a brief account of the recent work of Kiaer† and Stensiö‡ on the primitive Silurian chordates of Norway and of Spitsbergen. These investigators had more

* Stetson, Henry C., 1928. A new American Thelodus. Amer. J. Sci., xvi, pp. 221-231, illus.

† Kiaer, Johan. 1924. The Downtonian Fauna of Norway. I. Anaspida, with a geological introduction. Videnskapsselskapets Skrifter. I. Christiana.

‡ Stensiö, A. son 1927. The Downtonian and Devonian Vertebrates of Spitsbergen. Part I: Family Cephalaspidae, two volumes, illustrated with 112 plates, 103 text figures. Oslo.

beautifully preserved specimens than has ever before fallen to the lot of those interested in their structure. Stensiö especially has worked out the entire cranial anatomy—the brain and nerves, the vascular system, and has described and illustrated his findings in an attractive way.

The Cephalaspidae had a broad head shield, and this is all that is usually found, often in detached fragments. No fins are known, and in a single case were anterior trunk scales found, so that the form of the body is unknown. The softer tissues disintegrated and left no trace.

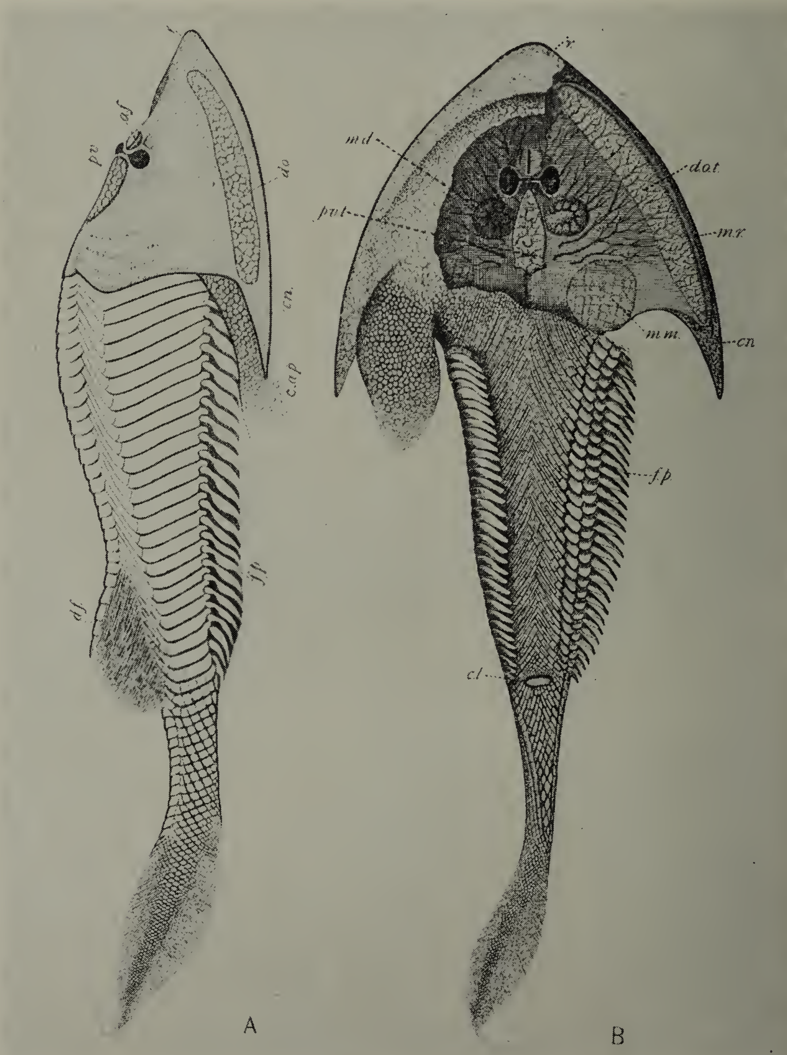

Fig. 7. A restoration of *Cephalaspis*, mainly after *murchinsoni*, a cyclostome-like chordate found abundantly by Stensiö in the Downtonian of Spitsbergen, shown in lateral and ventral views. The head-shield is all that is usually preserved. After Patten.

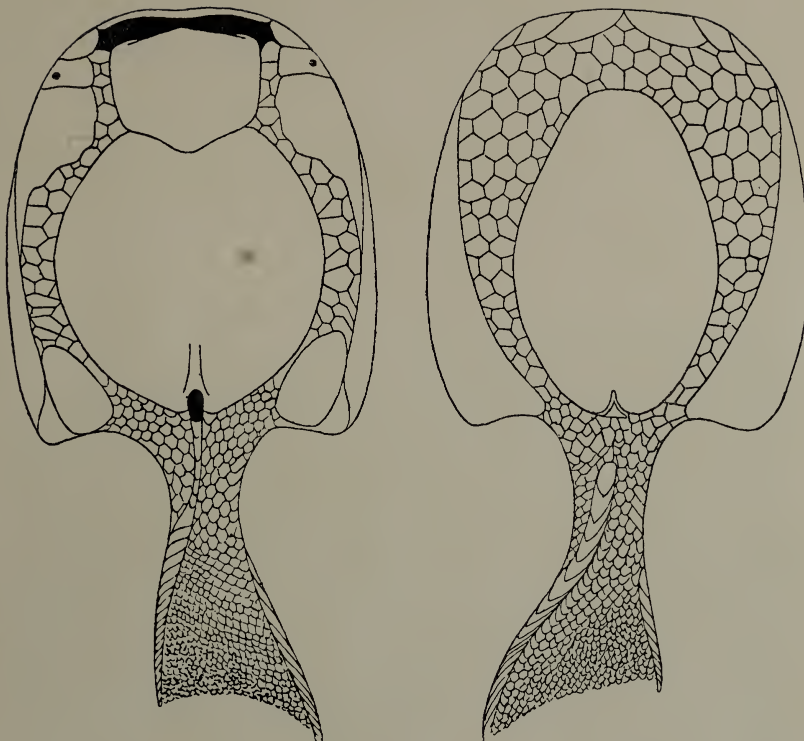

Fig. 8. An early chordate found in Europe, dorsal and ventral views, called by Traquair *Drepanaspis gemündenensis,* based on crushed specimens. The creature was without true jaws, had small ocular organs, no sense of hearing, probably lived on the bottom. After Kiaer.

The eyes were close together on top of the shield which was flattened ventrally and depressed, indicating that these ancient chordates were bottom feeders, and had to watch for enemies from above. They had no true jaws so they doubtless fed by sucking in mud and sand containing small animals and plants. They were only a few inches long and were helpless except in a passive way. Oddly enough there seems to have developed in these creatures electric fields occupying depressed areas which in some forms were covered by numerous small, polygonal plates. The endoskeletal parts were bone-like and strong. Histologically the skeletal parts only remotely resemble bone.

The head shields of the Silurian chordates, the Pteraspidae, found in eastern United States, rarely measure more than two or three inches in length, so the entire animal could not have exceeded 8 or 10 inches. They escaped their enemies by their inconspicuousness and sluggish nature. Partly buried in mud and protected by drab armor, they would not induce an inviting appearance.

These small creatures existed until lower Devonian times, and were contemporaneous with the Cephalaspidae, which Stensiö thinks were related to the cyclostomes or lampreys—eel-like creatures.

This author* has described the sensory canals of two early genera of acraniate chordates, which are rather narrow tubes within the dorsal and ventral shields. The canals are situated in the middle cancellous layer of the material forming the shields. From these definite canals, run off numerous tubules, usually rather short, which go out alternately to the right and left sides of the main canals and open in conspicuous pores. These passages were doubtless for direct communication between vibrations in the water and the receptive end organs within the canals. We thus have a suggestion of the nature of ancient lateral line sense organs.

Fig. 9. Photograph of the anterior part of the fish-like animal, *Drepanaspis gemündenensis* Traquair, showing the actual fossil, unusually well preserved.
MDPL: Median dorsal plate. O: orbit. OPL: Oral plates. RPL: rostral plate. From Kiaer after Traquair.

Other sense organs present in these chordates are those of sight, smell, and some specialized function represented by the pineal. These creatures could not hear but were conscious of slow wave vibrations by means of the lateral line system. They had no cochlea.

The gills were six or seven paired, protected by the dorsal head shield. Water breathing was their sole method of obtaining oxygen.

Odd, minute, tooth-like bodies called *conodonts*† (Figure 10) occur-

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* Stensiö, Erik A: son. 1926. On the sensory canals of Pteraspis and Palaeaspis. Archiv f. Zoologi, xviii A. No. 19, p. 1.

† Ulrich, E. O. and Bassler, R. S. 1926. A classification of the toothlike fossils, Conodonts, with descriptions of American Devonian and Mississippian species. Proc. U. S. National Museum, 68, 1-63, 11 pls. Holmes, Grace B., 1928. A bibliography of the conodonts with description of early Mississippian species. Proc. U. S. National Museum, 72, 1-38, 11 pls.

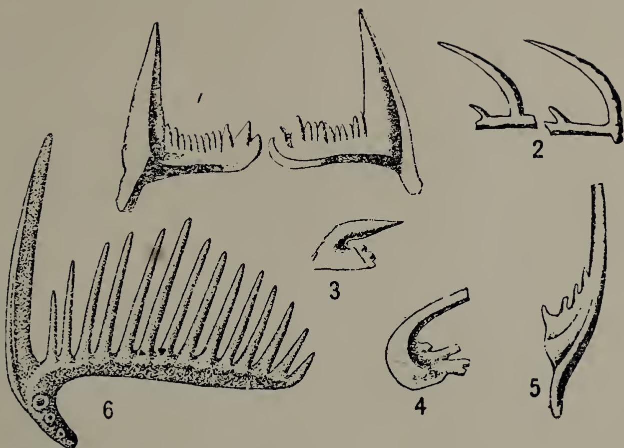

Fig. 10. Some American and European Conodonts, possibly to be regarded as teeth of primitive, shark-like fishes, otherwise unknown. After Bassler and Ulrich.

ring in many formations of the mid-Paleozoic rocks are thought by some writers to be the teeth of small, shark-like fishes. They rarely measure more than 2 or 3 mm. in length, and at times they occur in the rock deposits in incredible numbers. Usually they are of a dark brown to glistening black, often resembling small combs. In the papers cited these objects are said to be of service in determining the position of a rock deposit. No skeletal parts are ever found with them, and except that they exhibit right and left forms little is known of their nature. Some who have studied these objects regard them as jaws of annelids.

Conodonts are known in abundance in rocks of Devonian and Mississippian age but the group, whatever it was—fish or annelid—became extinct near the close of the Paleozoic, and has never reappeared.

If we could, in imagination, transport ourselves back into Silurian times when the early fish-like chordates lived, we would be able to appreciate more readily how different conditions were then from what we find them today. The sun shone then as now; clouds formed and rain fell; the winds blew and ice formed and thunder was probably heard, if there were any to hear. Scorpions and thousand-legged worms were the only air-breathers. There were no land vertebrates. Land plants were few and low. Aquatic plants were found along the coastal embayments where the rocks formed protecting walls. Development of the vertebrate group depended on the expansion of plant life.

Noises in the Silurian were nearly all due to the weather, to the rush of rivers, to the winds, to thunder and the lashing of waves. There were no trees and the only noises due to animal life were the occasional splashes of giant cephalopods as they pursued their prey in ocean waters. We might realize that the only individuals of the vertebrate groups, which later were to rule the world, were small, inoffensive, timid, bottom-living, fish-like chordates, inhabiting the fresh water pools near

Fig. 11. A paleogeographic map of North America showing location of continental seas in Paleozoic time. After Schuchert.

Fig. 12. A paleogeographic map of North America showing land and water conditions during the Upper Silurian. It must be remembered that the early chordates were fresh-water animals and lived at some distance from these marine basins. After Schuchert.

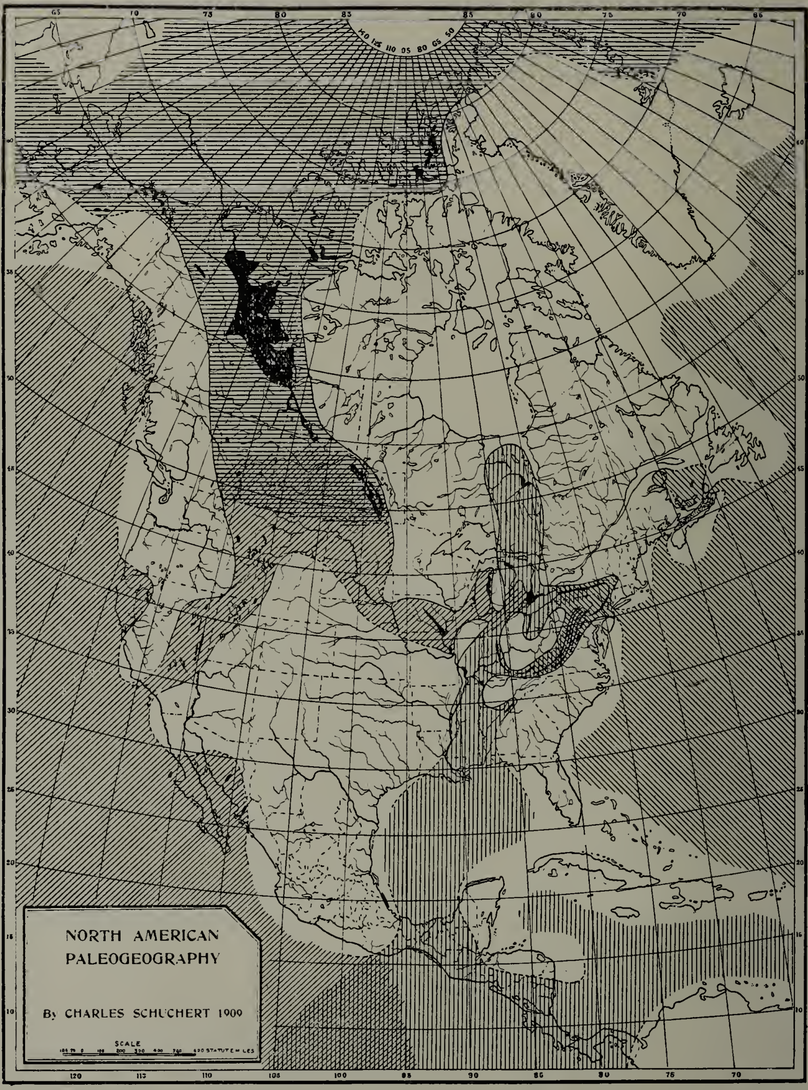

Fig. 13. A paleogeographic map of North America showing expanse of continental seas during the middle Devonian, at which time the Age of Fishes was being established. After Schuchert.

shore or shallow, brackish water bayous. These creatures had no ears capable of hearing, but they depended on their skin sensory organs which were capable of perceiving slow wave vibrations which would warn them of danger. Altogether the Silurian was a very quiet time, but in it were those forces which would later lead to the development and expansion of all vertebrates.

THE FISHES OF THE DEVONIAN IN INDIANA AND ITS ENVIRONS

The Devonian period is well called "The Age of Fishes." During this time many groups of fishes were developed and spread all over the world. We do not know the origins of all the groups, but some are indicated among the Silurian chordates. The possession of heavy defensive armor is common, reaching an extreme development in the head region of the Arthrodira, the superdreadnaughts of the Paleozoic seas. The presence of armor in animals is not an indication of relationship.

Armor among the Devonian fishes consisted of defensive spines, bony plates, cephalic shields, hard and over-lapping scales, and armored appendages. Much of this early defensive armor consisted of osteodentine, but later types were protected by bone. It is thought that the possession of heavy, defensive armor of spines and plates is an indication that the animal group is approaching extinction. It is true that the bizarre, armored creatures of the Paleozoic did not survive the Devonian.

It seems probable that the most primitive defenses of the early vertebrates consisted in scattered plates, tubercles, and scales imbedded in the skin. These defenses became more effective when the adjacent hard parts fused. An account of the structure of the fishes will be given under the different groups.

The various groups of fish-like vertebrates in the Devonian rocks of North America are sharply marked from each other. The Ostracoderms are brought over from the Silurian; ancient and generalized sharks have developed and are known best in the Devonian by the genus *Cladoselache*. The enamel-scaled fishes, the ganoids, begin their long career in this period. True lung-fishes, dipnoans, are found for the first time in these rocks. These dipnoans have persisted throughout all geological time and exist today in the tropics of Africa, Australia and South America, but little changed from their Paleozoic ancestors. A group of large armored fishes, called Arthrodira lived only during the Devonian. Eastman relates them to the lung fishes. Stensiö regards them as affiliated with the sharks—the Elasmobranchs. These fishes were the giants of their day, the rulers of the Paleozoic seas. Modern groups of fishes are foreshadowed by some of the Devonian fishes, but the Arthrodires left no descendants. We do not know their origin, nor why they perished. They played their part in life and disappeared. Perhaps the most interesting of all the Devonian fishes were those crossopterygian forms which appear to possess the germs from which land vertebrates grew. All students are in practical agreement that vertebrate descent is to be traced through this group of crossopterygians.

The intermediate steps are still unknown, but future discoveries will doubtless reveal the manner in which this development took place.

The large size and abundant and diversified forms of Devonian fishes is regarded by some students as being in response to the increased supply of food, both plant and animal. In the Silurian we noted the small size of the primitive vertebrates, correlated with scant plant growth, and active, large invertebrate enemies. Possibly before the close of the Silurian the vertebrates began to expand and attained supremacy very quickly in Devonian seas, that is, as we regard geological time. It doubtless took millions of years to bring about this condition of affairs in vertebrate life.

Fig. 14. A fossil fish aquarium in the American Museum of Natural History, showing the various types of Devonian Fishes, based on studies by Bashford Dean.

THE OSTRACODERMS

The ostracoderms, as at present known, constitute a group of primitive, agnathous, armored cyclostomes, of such diverse organization that the group must, with additional material and further study, be subdivided into several groups. The group became extinct during the Devonian and none is known from Indiana, yet to understand the Devonian vertebrates we must include a discussion of them. They were not a dominant group. They were bottom-living animals, rather shunning notice, and hiding from their enemies rather than fight it out with them. In truth they were defenseless, their chitinous armor furnished but little protection. Some of them were practically blind, and their powers of locomotion were limited.

The group reached its maximum development during the Upper Silurian, after which it rapidly declined and became extinct before the close of the Devonian. During its brief career, however, it attained a wide range of habitat, being known from Norway, Spitsbergen and eastern North America (Figures 14, 15, 16).

Most of the ostracoderms were small (Figure 7), usually a few inches long. Two species are known which may have attained a length of two feet. They inhabited shallow, brackish or fresh waters, and swam, flat surface down, through the soft mud, feeding on the minute plants and animals as they went. Most ostracoderms have large rounded or pointed heads, a small trunk, and possibly a long slender tail.

Fig. 15. An American Devonian Ostracoderm, *Bothriolepis canadensis,* showing in dorsal view the structure and appearance of this curious chordate. It is possibly closely related to the modern cyclostomes. After Patten.

The mouth parts of the ostracoderms (Figure 9) differ from other known chordates, and were composed of dermal and basal parts, without true jaws, a condition which some think places the animals in a separate group. Others regard them as cyclostomes.

ANCIENT SHARKS

There are several groups of shark-like fishes in the Paleozoic, our knowledge of which is restricted to teeth, usually isolated, fin spines called ichthyodorulithes, and other dermal defenses. Such fossils range in age from the Silurian to the close of the Paleozoic. Our knowledge of the nature of the Paleozoic sharks is in great confusion. It is obvious that isolated spines, teeth and scales may all belong to the same creature, although the parts may be known by half a dozen different names. The

Fig. 16. The same animal from the ventral surface. After Patten.

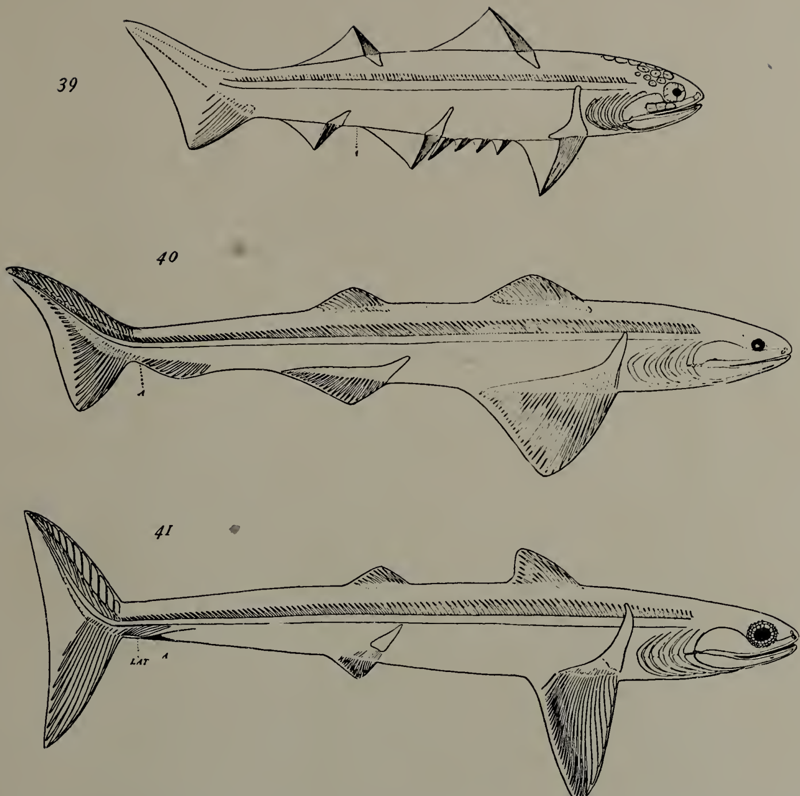

Fig. 17. Cladoselachian fishes as they looked in life. The restorations are based on a large number of specimens collected in the Cleveland shale in Ohio. After Dean.

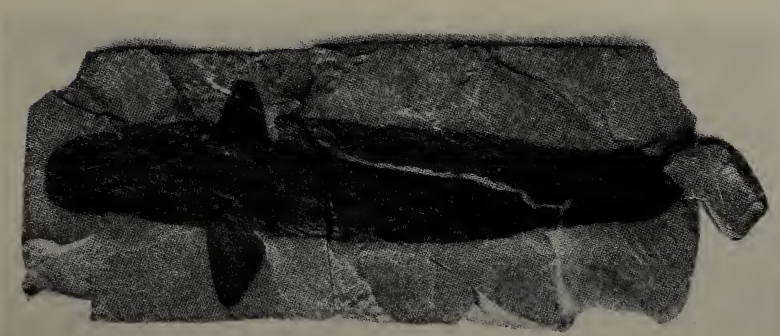

Fig. 18. A Devonian shark as it was preserved in the rock. The body was crushed flat and inclosed in a concretion. After Dean.

endoskeleton of all sharks is soft cartilage, rarely stiffened by deposits of calcium. It is only by the rarest good fortune that a fossil shark is represented by any associated parts. It is also obvious that several species of fossil vertebrates may be founded on different shaped teeth from the mouth of a single shark.

The cladodont sharks, represented by the ten or more species of *Cladoselache*, are known from fairly complete remains found in black Devonian shales, near Cleveland, Ohio.* Not only are the hard parts, teeth and scales, the stiff cartilages of the endoskeleton, and the form of the fins completely known, but we also know the miscroscopical nature of the muscles and kidneys, their food, the lateral line canals, the form of the body, the thin fold connecting the pectoral and pelvic fins, as well as the intimate relations of many of the tissues which are so seldom preserved in fossils.

Fig. 19. Teeth from a Devonian shark. After Dean.

While these sharks are thought to have been inhabitants of salt water, yet it has been suggested that the wonderful preservation of the soft parts, within the hard concretions, was due to the inclusion of the dead fishes within soft mud of brackish or fresh-water estuaries. Concretions, with the entire shark or parts of the shark as nucleus, may attain a length of six feet. They are very heavy and weather out slowly from the black shale in which the concretions were found. Other fishes are found fossilized within the concretions, especially parts of the arthrodires, which Stensiö would have us believe are only highly modified sharks. Remains of *Cladoselache* have been collected at Cleveland for more than half a century.

The cladoselachians had a brief history, geologically. Their remains are known from the upper Devonian of New York and Ohio, and from the lower Carboniferous of Kentucky. They were Paleozoic sharks having a notochordal axis, and with paired fins of a peculiarly primitive type. The caudal fin is turned up abruptly. The scales, protecting the body, were small in size and inconspicuous. Only around the eyes did they attain any size, forming sclerotic shields. The absence of an intromittent organ from the pelvic fins leads us to assume that these early sharks did not produce living young, as modern sharks do, but spawned. The cladoselachians were all fairly small, individuals attaining a length of five feet being rare.

*Hyde, J. E. 1926. Collecting fossil fishes from the Cleveland Shale. Natural History, xxvi, 497-504, illus.

The dentition is fully known. The teeth were trifid, set on a broad base, arranged in about a dozen banks of teeth, each including seven or eight close-set elements. The vasodentine is very thick, and there is no enamel. The gill arches number from five to seven. They were slender and extended far posterior. The fins, supported by radial cartilages, were connected by a lateral dermal fold.

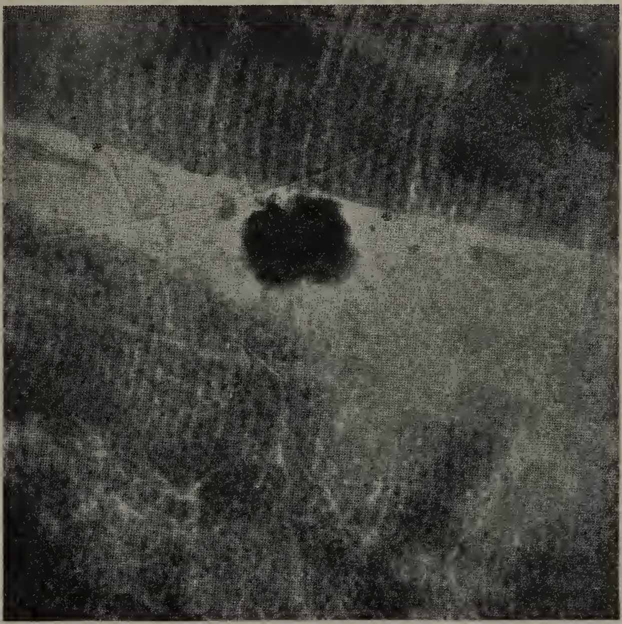

Fig. 20. Photomicrograph of muscle fiber of a Devonian shark, showing cross striations, typical of voluntary muscle. x1000. After Dean.

DEVONIAN CHIMAEROIDS

The chimaeroids, or rat-tailed fishes, are brilliantly colored marine animals, known chiefly to the modern professional zoologists who are interested in them because of their isolated position among fishes, and for their very long and practically uneventful geological history. The fishes have no commercial value and are seldom seen in aquaria. The modern fishes are soft bodied, with few dermal defenses.

These animals are known from abundant and widely scattered dental plates, called "tritors," and fin-spines, in the Devonian rocks of America and Europe. The group is represented at a Devonian locality in Iowa by thousands of water-worn tritors, all contained within a few square yards of rock surface, indicating vast numbers of the fishes at that time. Nothing is known of the bodily form of these Paleozoic fishes, and not until the Jurassic do we find imprints of the soft body. Dean has described a specimen, three feet long, from the lithographic slates of Bavaria, representing an entire fish.

The habit of depositing large egg capsules in which the young developed is as old at least as the Cretaceous of Wyoming, where a complete capsule was found, differing only in details from a modern capsule.

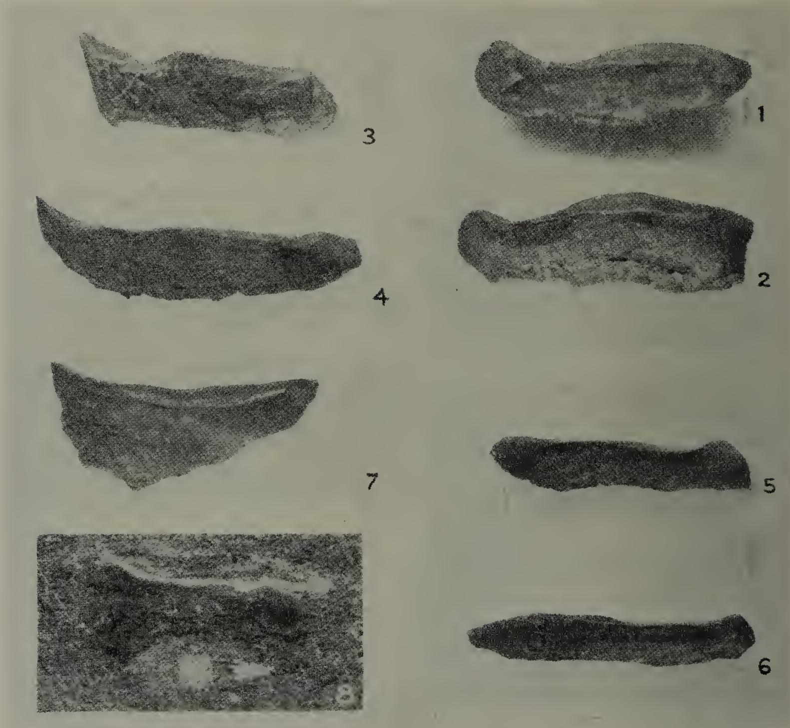

Fig. 21. Tooth-like grinding plates, called "tritors," of a Devonian chimaeroid from Iowa. After Eastman.

THE ARTHRODIRA OR ARMORED FISHES

One of the earliest and most important discoveries of arthrodiran remains was made in Indiana when, in 1846, Norwood and Owen (see bibliography) announced the discovery of a primitive fish to which they assigned the lengthy name of *Macropetalichthys rapheidolabis*, a name which still holds good after more than three quarters of a century. The type specimen was exhibited at the Cincinnati meeting of scientists in 1851, where it was examined by the famous ichthyologist, Louis Agassiz. Newberry mentions it in 1862. Later the specimen was acquired by the University of Missouri. It was redescribed in 1891 by Cope, and a few months later it was destroyed by fire, together with the entire contents of the museum to which it belonged. Recently (see bibliography) Stensiö, after studying undescribed material in the Field Museum

of Natural History, has monographed the group and concluded that these primitive arthrodirans are more nearly related to the sharks, the true elasmobranchs, than to any other known group, thus denying their dipnoan affinities as sponsored by Eastman. The six page bibliography given by Stensiö shows the active interest paleontologists have taken in these fishes.

Fig. 22. The bones of the head and shoulders of one of the largest Devonian fishes, *Dinichthys*, as mounted in the American Museum of Natural History. Dorsal and anterior views.

Fig. 23. The same, shown in lateral view.

These huge fish-like animals of the Paleozoic, the "joint-necks" or arthrodires, flourished in Europe and America from the late Silurian to the Lower Carboniferous. During this great stretch of time the arthrodires expanded into about two dozen genera, representing a dozen families and at least three orders (Dean). Their remains are often surprisingly well preserved, but one geologist believes that much more can be learned of these fishes by more careful methods of collecting. Little is known of the bodily form of the larger species, and we are not sure to what group of fishes they are the most closely kin. They have been regarded by various authors as related to the sharks, the chimaeroids, the teleostomes, and the dipnoans.

These fish-like chordates were often of huge size. The largest member of the group, *Titanichthys clarki,* attaining a probable length of twenty feet, is the largest fossil vertebrate found up to the close of the Devonian period. The cranial and shoulder parts of another large genus, *Dinichthys* (terrible fish), have been mounted in the American Museum of Natural History and in the Buffalo Museum of Natural Sciences. Some of the head parts show scars which indicate its ferocious nature—the scars having been made by other arthrodires. When one considers their huge bulk, their capacious mouths and ferocious natures, they may well be considered the rulers of the Devonian seas. Their great bulk would require great quantities of food.

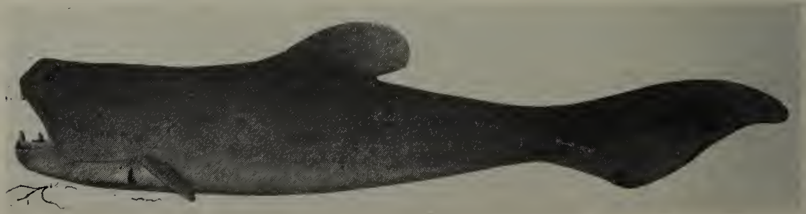

Fig. 24. Restoration of an arthrodire.

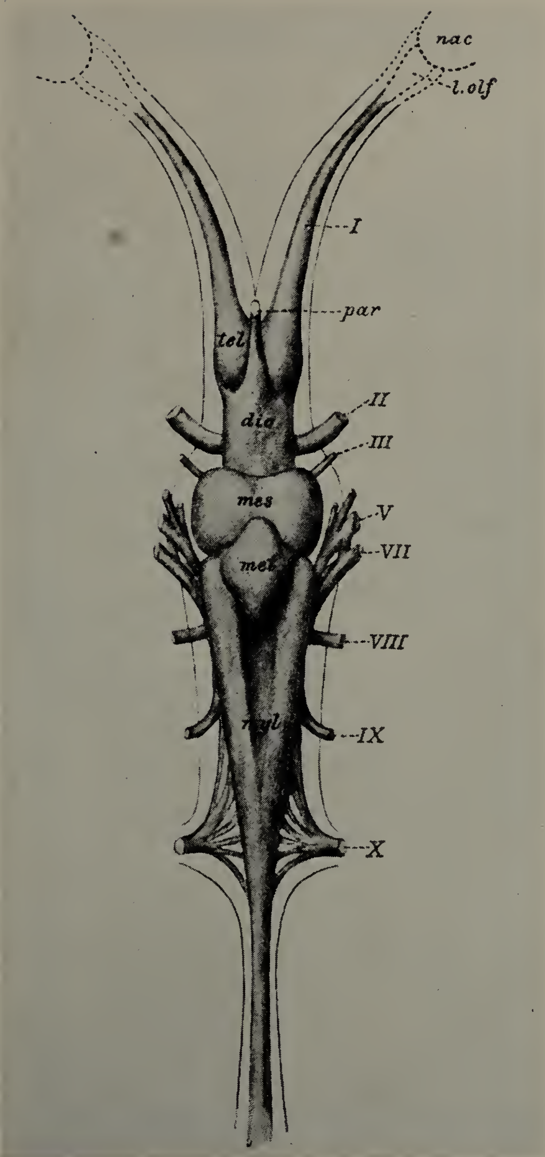

Fig. 25. Hypothetical shape of brain of the Indiana arthrodire, *Macropetalichthys rapheidolabis*, from above in relation to the endocephalic space.
dic, diencephalon; *l.olf*, lobus olfactorius; *mes*, mesencephalon; *met*, cerebellum; *myl*, medulla oblongata; *nac*, nasal pit; *par*, parietal or pineal organs or both; *tel*, telencephalon; *I*, tractus olfactorius; *II*, n. opticus; *III*, n. oculomotorius; *V*, roots of trigeminus proper; *VII*, facialis and trigeminus; *VIII*, n. acusticus; *IX*, p. glossopharyngeus, *X*, n. vagus. After Stensiö.

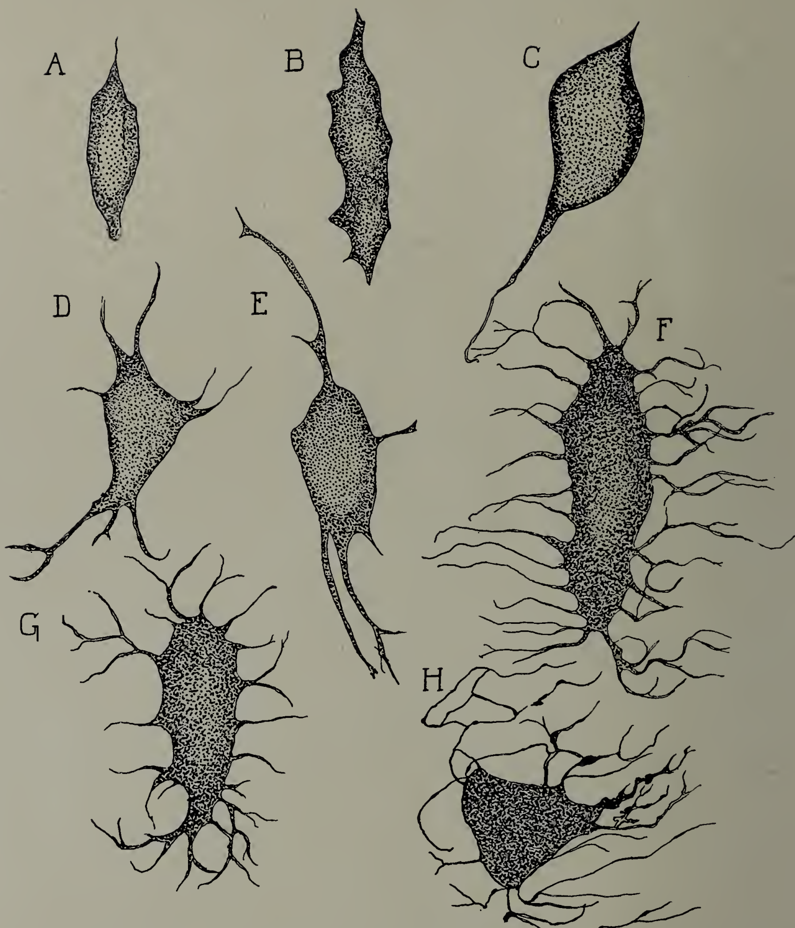

Fig. 26. A group of osseous lacunae from ancient vertebrates showing comparative size and form in different geological ages.

A, Dinosaur, Comanchian of Wyoming; B, spine of a Permian reptile, Red Beds of Texas; C, skull of mosasaur, Cretaceous of Kansas; D and E, marine reptile, Cretaceous of Kansas; F, fossil mammal, Oligocene of Nebraska; G, vertebra of sabre-tooth, Pleistocene of California; H, human, recent.

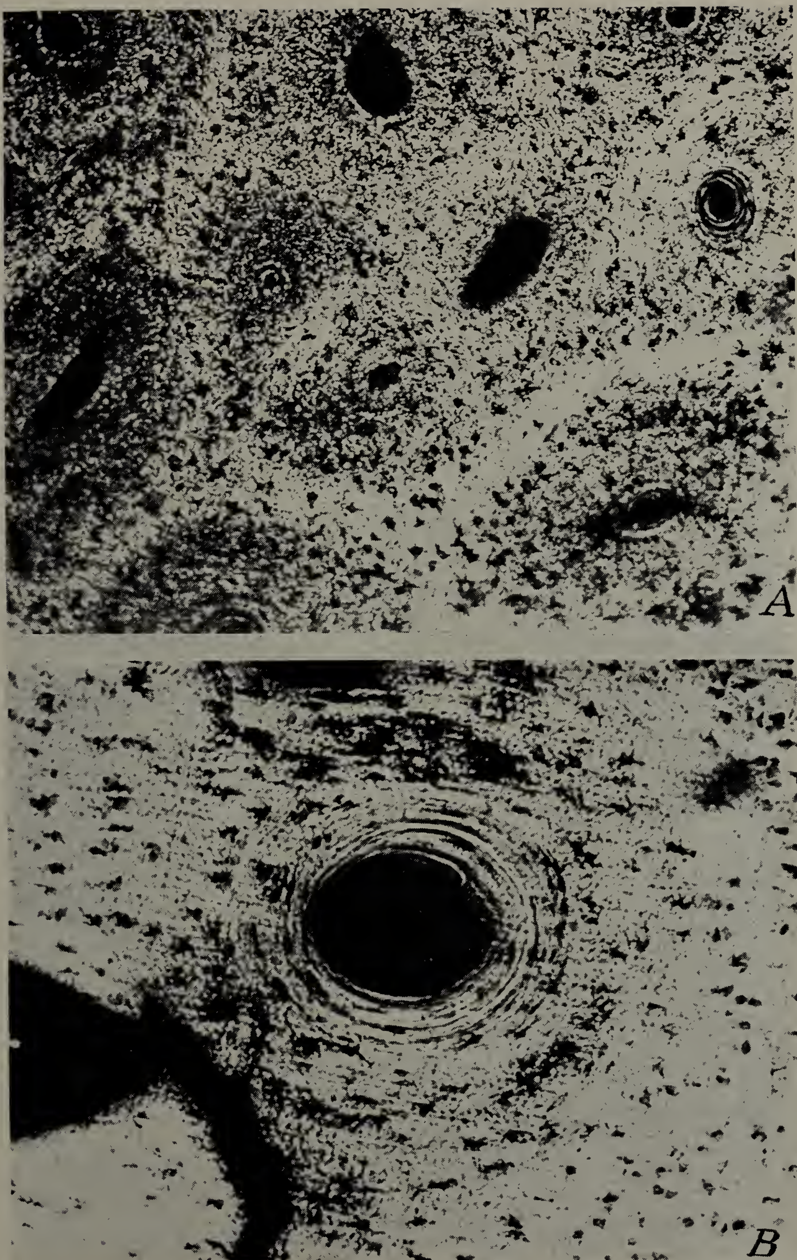

Fig. 27. Histology of bone of the Devonian arthrodire, *Dinichthys*, showing arrangement of primitive Haversian systems.

Fig. 28. A small fossilized arthrodire, *Coccosteus canadensis*, about five and a half inches long, from the Devonian rocks of Scaumenac Bay, Canada. Original in the New York State Museum. After Hussakof.

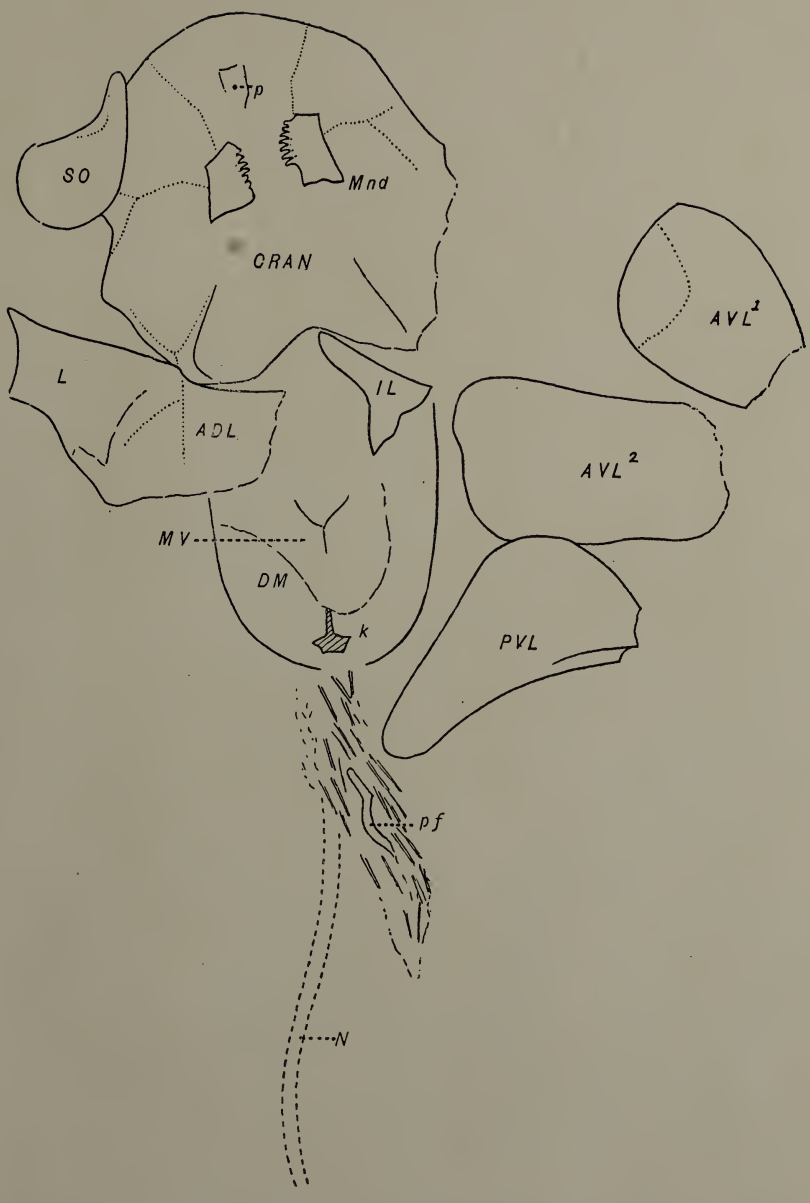

Fig. 29. Outline drawing of the specimen of Coccosteus canadensis Woodard, shown in figure 28.

ADL, anterior dorsolateral; AVL[1], AVL[2], anterior ventrolaterals; CRAN, cranium; DM, dorsomedian; IL, interlateral; k, "keel" of dorsomedian; L, lateral; Mnd, mandibles; MV, median ventral; N, impression of notochord; p. pineal opening; pf, "pelvic fin support" · PVL, posterior ventrolateral; SO, suborbital. After Hussakof.

The great majority of the group were marine animals, the fishes having gone to the seas from fresh water before Devonian times. A small member of the group, *Coccosteus canadensis* Whiteaves, measuring only a few inches in length, is known from fairly complete material.

The histological structure of the bone in these ancient fishes has attracted much attention,* since it is here that we find the earliest examples of the arrangement of the osseous elements in Haversian systems. All of the essential elements of the system are present. The lacunae are relatively large and the canaliculi well preserved, though never intercommunicating. The Haversian canal is large and extensive. The lamellae stand out clearly. The lacunae of *Coccosteus* differ slightly from those seen in *Dinichthys*, and the Haversian canals are larger.

Bacteria and fungi have been found in the lacunae of *Coccosteus*, these organisms being those of a destructive putrifying nature, rather than indicating disease.

THE LUNG-FISHES

Lung fishes were long regarded as the forerunners of the land vertebrates because of their ability to survive without much water, due to their peculiar respiratory mechanism. Barrell has shown that the dipnoans, as the lung fishes are called, probably acquired this life-saving ability in Silurian-Devonian times, on account of changes of climate. Gregory has given the anatomical reasons why the lung-fishes of the Devonian were not the ancestors of the Amphibia. This group of fishes, known chiefly from dental plates, has survived from Paleozoic times little changed. Dipnoan teeth are characteristic features of many geological horizons. Fairly complete specimens are known from the Devonian and from the Carboniferous.

Fossil lung fishes were first made known by Hugh Miller, the stone-cutter of Cromarty, Scotland, who as a quarryman in the Old Red Sandstone, collected many fossilized remains of Devonian fishes. He made known the anatomy of the early lung fishes so completely that little has been added since. Representatives were later found in America and the Devonian rocks of several states have furnished the remains of a number of species. The fishes are never large. Those collected in the Devonian of Quebec† measure from 3¼ inches to 18 inches, and are often very completely known. The Devonian species are thus about the size of modern lung fishes. The scales and lateral line organs resemble those of modern species, as do the teeth, skull and fins. We may assume that the habit of the modern fishes of aestivating in a ball of mud

* Moodie, Roy L., 1926. Studies in Paleopathology, XIII. The Elements of the Haversian System in normal and pathological structures among fossil vertebrates. Biologia Generalis, XI, with 12 plates.

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† Hussakof, L., 1912. Notes on Devonic Fishes from Scaumenac Bay, Quebec. N. Y. State Museum Bull., 158, pp. 127-139.

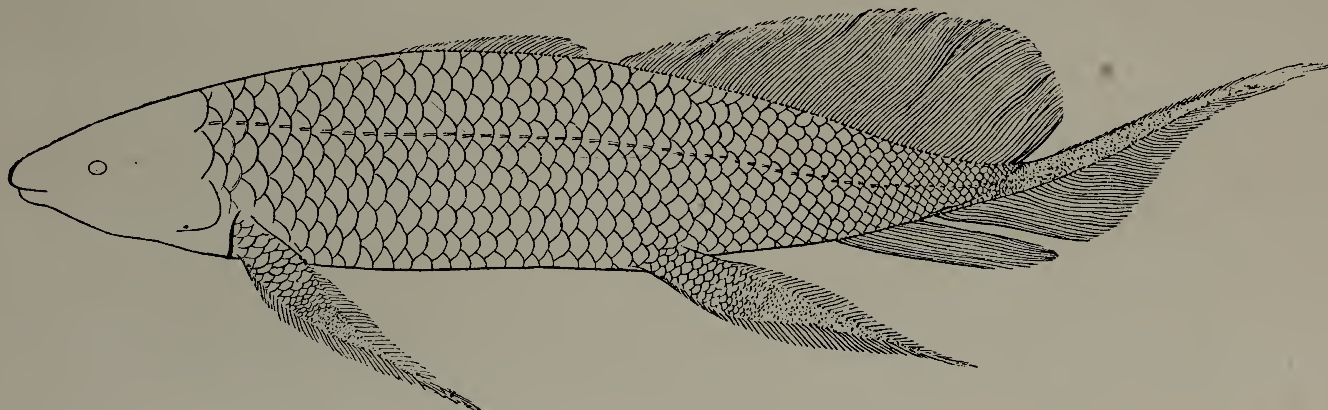

Fig. 30. Restoration of a Devonian Lung-fish, *Scaumenacia curta*, from rocks of the Upper Devonian of Scaumenac Bay, Canada. After Hussakof.

Fig. 31. Fossilized remains of an Upper Devonian Lung-fish, *Scaumenacia curta*, as preserved in a nodule. Original in the New York State Museum. After Hussakof.

Fig. 32. Another fossilized lung-fish of the same species, showing the tail especially well. Same horizon as above. After Hussakof.

during the dry season had its inception during the Devonian, when the climatic changes were severe enough to have been recorded in the rocks.

The Indiana region has furnished a large number of fossil lung fishes, represented chiefly by dental plates. In certain cases cranial plates which lay on a cartilaginous skull are found, usually single, rarely associated. Eastman divides the lung fishes into three groups, of which he considers the arthrodires to be one. This extreme view is not followed by other writers on Paleozoic vertebrates, and in this paper the Arthrodira are considered separately.

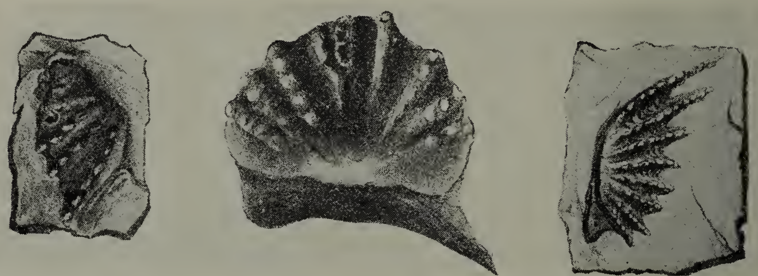

Fig. 33. The teeth of a Lung-fish. They retained the same form through the geological ages. After Eastman.

THE ENAMEL-SCALED FISHES

Small, ganoid fishes of the Family Palaeoniscidae are represented in the Devonian by species of *Rhadinichthys.* The group will be more fully discussed under the Carboniferous and little need be said here save to record the occurrence of several species of these primitive sturgeons, differing even in the lower Devonian when the Paleoniscidae are represented by the genus *Cheirolepis.* The Chrondrostei, or sturgeons, occur throughout the Mesozoic period and show a gradually diminishing representation during the Cenozoic, and down to the present time. The heads of certain small fishes of the genus *Rhadinichthys,* enclosed in nodules, show well preserved brains, semicircular canals, arteries, nerves and other soft structures.

CROSSOPTERYGIAN FISHES OF THE DEVONIAN

The group of fishes called Crossopterygians, are regarded as the direct ancestors of Paleozoic and modern land vertebrates. Among the many fish-like vertebrates found in Devonian rocks of North America none possesses a greater interest than the crossopterygians, of which there are several known genera. The best known species is the fish, *Eusthenopteron foordi,* known from nearly complete skeletal remains from the upper Devonian of Canada, where one example three feet long has been described. We shall discuss briefly the anatomical characters of this fish, as described by Bryant.*

* Bryant, W. L., 1919. On the Structure of *Eusthenopteron.* Bull. Buffalo Soc. Nat. Sci., xiii, pp. 1-22, plates 1-19, figs.

Eusthenopteron was a rather slender, round bodied fish. It was an active, voracious animal of predatory habits. Its head occupied a little more than one quarter of its length and its greatest depth was contained more than five times in its total length (Figure 34). The body was covered with rather small cycloid scales, and a single enlarged ridge scale occurs immediately behind each of the dorsal and anal fins. The scales are formed of three layers of osteoid tissue resembling true bone. The bones of the skull are thin and in their arrangement resemble those of the later amphibians (Figure 35). The orbits are rather small, with

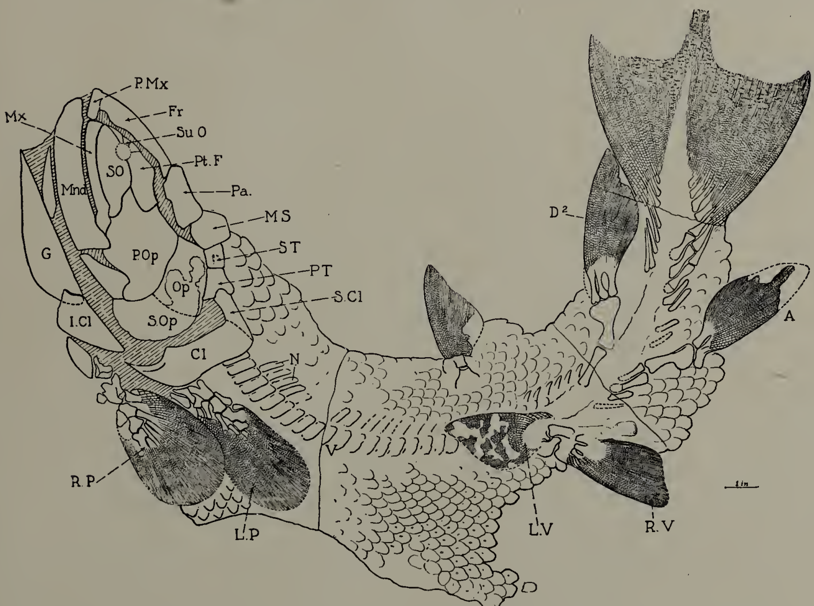

Fig. 34. *Eusthenopteron Foordi*, Whiteaves, Scaumenac Bay, Quebec. Specimen in New York State Museum.

A, anal fin; Cl, cleithrum; D¹, D², dorsal fins; (D¹, accidentally omitted in lettering, should indicate the fin in front of D²) Fr, frontal; G, gular plate; I. Cl, infraclavicle; L. P, left pectoral; L. V, left ventral; Mnd, mandible; MS, median supratemporal; Mx, maxilla; N, neural spines; Op, operculum; Pa, parietal; P. Mx, premaxilla; P. Op, preoperculum; PT, posttemporal; Pt. F, postfrontal; R. P, right pectoral; R. V, right ventral; S. Cl, supraclavicle; SO, suborbital; S. Op, suboperculum; ST, lateral supratemporal; Su. O, supraorbitals; V, vertebral centra. After Hussakof.

sclerotic plates defending the eye. The lower jaw is long, slender and beset with teeth, and cut by the lateral line canals, as are the bones of the skull.

The pectoral fin (Figure 36) partakes of the structure of a limb, and on its structure is founded, largely, the suggestion that this group of fishes stood in an ancestral position to the land vertebrates. Its parts are regarded as homologous with those of the tetrapod limb. Naturalists the world over are agreed that the crossopterygians and the amphibians have a genetic relationship.

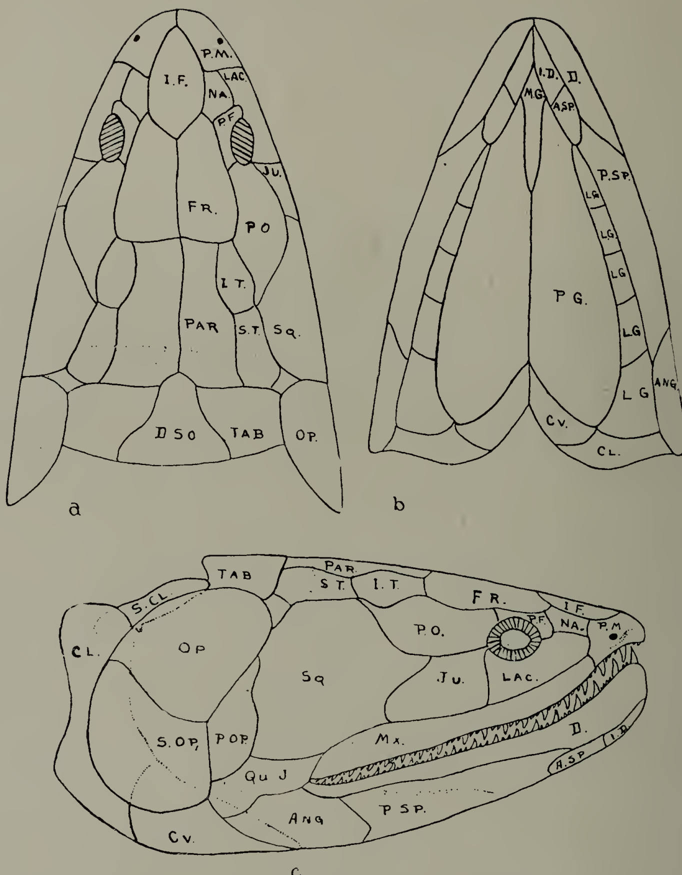

Fig. 35. Skull Pattern of *Eusthenopteron foordi* Whiteaves. a dorsal, b ventral and c lateral view. Ang., Angular; A. Sp, Anterior splenial; Cl, Cleithrum; Cv, Clavicle; D, Dentary; D. So, Dermosupraoccipital; Fr, Frontal; I. D, Infradentary; I. F, Interfrontal; I. T, Intertemporal; Ju, Jugal; Lac, Lacrymal; L. G, Lateral Gular; M. G, Median Gular; Mx, Maxilla; Na, Nasal; Op, Operculum; Par, Parietal; P. F, Prefrontal; P. G, Principal Gular; P. M, Premaxilla; P. O, Postorbital; P. Op, Preoperculum; P. Sp, Posterior Splenial; Qu. J, Quadratojugal; S. Cl, Supracleithrum; S. Op, Suboperculum; Sq, Squamosal; S. T, Supratemporal; Tab, Tabulare. After Bryant.

(Sensory canals indicated by double dotted lines.)

The transformation of animals from fishes to amphibians involved the loss of the tail as the chief propelling organ; the loss of dorsal and anal fins, and their expanded basal supports; the loss of a completely scaled condition, for some of the Coal Measures amphibians possessed scales; great muscular adjustments: the acquirement of lungs and air-breathing; and change in food habits.

Fig. 36. A fossilized left pectoral fin of a crossopterygian fish, *Eusthenopteron foordi*, Whiteaves, with its supports which are thought to represent the arm bones of the higher animals. After Bryant.

THE DAWN OF MODERN FISHES

There can be no doubt that the various groups of modern fishes were outlined early in the Devonian or even in the Silurian. The cyclostomes, or lampreys, were represented in these periods by the ostracoderms. True sharks are foreshadowed by species known from teeth and spines; by the cladoselachians and possibly the arthrodires

which Stensiö regards as elasmobranchs. The Chimaeroids began their enormous history of many, many millions of years during the Devonian and have changed but little in all subsequent geological time. True lung-fishes are fairly abundant in Devonian rocks and are represented by well-preserved fossils. The group, known as Dipnoans, was firmly established during Devonian times and has had a long, subsequent history almost unchanged. The Crossopterygians are known today in scant numbers and have changed but little. The ganoid fishes, with the body protected by enamel scales, were established in early Devonian times.

Today the dominant group of fishes is the bony fishes, which are not represented among the fossil vertebrates known from Devonian rocks. Their history began later. The diverse modifications of the bony fishes have been accomplished in relatively recent times.

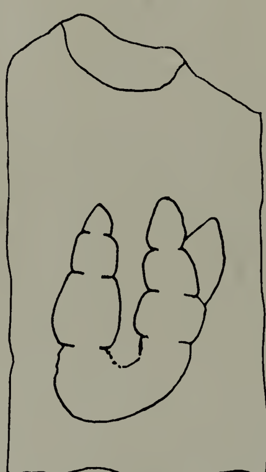

Fig. 37. The oldest known amphibian footprint, *Thinopus antiquus*, from the Upper Devonian of Pennsylvania. Track about four inches long. After Lull.

TRACES OF LAND ANIMALS IN THE DEVONIAN

Many years ago Professor Marsh of Yale University described, under the name *Thinopus antiquus*, a single footprint nearly four inches long which still remains the only evidence of land vertebrates during the Devonian. The track is from a marine sandstone of the littoral or beach area over which the animal walked, probably in search of dead marine animals. The footprint stratum is associated with others that are ripple-marked and sun-cracked, and bear rain imprints.

The imperfection of the track was not understood until Morton* by careful modeling showed how the middle toe may have been raised so as not to make a perfect imprint.

* Morton, Dudley J., 1926. Notes on the footprints of Thinopus antiquus. Amer. J. Sci., 5th ser. xii, 409-414. 6 figs.

Since scorpions, myriapods and other land-living arthropods are known to have existed during Silurian time, it is a safe assumption that their race was continued through the Devonian. Insects developed along with the expansion of plant life, and Devonian land plants are known. It was during the Devonian that the first forests* were developed.

FISHES WHICH LIVED DURING THE CARBONIFEROUS

Conodonts (see Figure 10) which may represent an otherwise unknown group of fishes, are found abundantly in rocks of Mississippian age in the states bordering on Indiana, and serve as time-markers for the subdivisions of that period (see papers by Ulrich and Bassler, and by Holmes). Conodonts continue in diminishing numbers throughout the rest of the Paleozoic, to disappear entirely shortly before its close.

Ichthyodorulithes are fin-spines, fragments of bone, and other osseous manifestations of fishes whose skeletons are largely cartilaginous. These objects and teeth (Figures 39 and 40), often found in marine deposits of the Mississippian and Pennsylvanian, represent nearly all we know of the elasmobranch fishes of this time. Rarely impressions are found which aid in correlating the known skeletal parts. It will be obvious that fin spines and teeth of different shapes, assigned to several genera and species, may be, in fact, parts of one and the same animal. Paleoichthyologists, aware of this, are always on the alert to correlate their finds as rapidly as possible, but a great deal remains to be done. As an example of this we may cite the example of the Carboniferous fossil called *Edestus*, a group of shark-like fishes known from a score of species, from several parts of the world. The tooth-bearing spine was for a long time thought to belong to the anterior dorsal fin, until a fortunate discovery enabled Dr. Hay† to show that the *ichthyodorulite* called *Edestus* was a part of the jaws of a Paleozoic Cestraciont shark. Another related shark, with similar oral defenses has been described from the Carboniferous of Russia.

A large number of *sharks* (Elasmobranchii), classified into several families, are known from the rocks of the Carboniferous system in Indiana and the bordering states. The various shapes assumed by the teeth give rise to names which are descriptive of the teeth, rather than indicative of relationship. Such terms as Cladodont, Petalodont, Cochliodont and the like give rise to family names as the Cladodontidae, Cochliodontidae and the other similarly named groups.‡ Such objects occur in rocks of Mississippian and Pennsylvanian age and have been elaborately figured and described in a large number of exhaustive reports and memoirs. One seldom sees them discussed within recent years. Paleontologists of half a century ago reaped the entire field.

* Goldring, Winifred, 1927. The oldest known petrified forest. Scientific Monthly, xxiv, 514-529, illus.

† Hay, O. P., 1912. On an important specimen of Edestus. Proc. U. S. Natl. Mus., 42:31-38, pls. 1-2.

‡ Eastman, Charles R., 1917. Fossil Fishes in the Collection of the United States National Museum. Proc. U. S. Natl. Mus., 52:235-304, pls. 1-23.

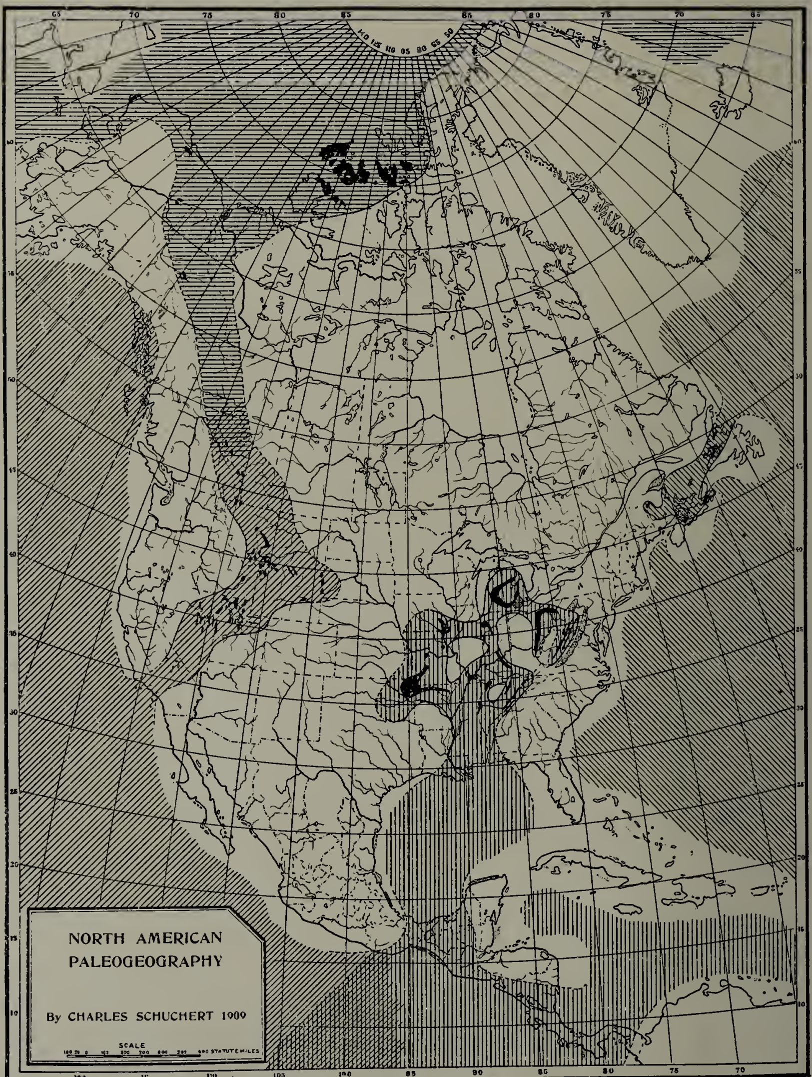

Fig. 38. A paleogeographic map of North America, showing details of land and water during the Middle Mississippian (Burlington) times. After Schuchert.

Fig. 39. Carboniferous spines *(ichthyodorulithes)* and teeth of sharks from rocks in the vicinity of Indiana.
1, 2, 2a: Shark's teeth of the genus, *Cladodus*.
3, 6: Fin spines of Mississippian sharks, *Oracanthus* and *Ctenacanthus*.
4, 5: Dentigerous plates of *Oracanthus*. After Newberry.

Fig. 40. Carboniferous shark's teeth of various forms. 1 to 3 represent the genus, *Diplodus;* 4 to 9 the genus, *Cladodus;* 10 to 14 five other genera. The teeth are usually found separate and there is little to show whether or not several of the species here shown represent a single fish. After Newberry.

Occasional discoveries enable us to correlate the scattered and variously named parts. Hundreds of species have been named from teeth and spines.

The known teeth (see papers by Branson in Bibliography) indicate a widely divergent mode of life. Some appear to have been fiercely carnivorous, with sharply pointed and cutting teeth, useful for retaining slippery prey as well as rending it into pieces small enough to be swallowed. Others with flat, quadrate, roughened plates appear to have been adapted to feeding on molluscs or crustacea, like the modern skates and rays, in which the chewing or crushing surfaces are covered with thin broad plates.

Fig. 41. Paleogeographic map of North America, showing distribution of land and water during the Pennsylvanian period. After Schuchert.

The ancient sharks, rays, skates, and their kin were, during the Carboniferous, dwellers in the open seas, very much as such animals live at the present time. The marine waters of the Carboniferous seas were plentifully supplied with hosts of invertebrates, an abundant food supply for the marauding sharks. None of the selachians were noted for unusual size. They were doubtless all moderate in dimensions, and are on the whole exceeded by modern species. During all subsequent time the elasmobranchs have changed but little. Their organization was fully established before the Coal Period ended.

Another group of cartilaginous fishes, the *chimaeroids*, shy and elusive as at present, inhabited ocean waters, and left their *tritors* as indicative of their presence.

The *Ostracoderms* and the *Arthrodires*, dominant types of the Silurian and Devonian, became extinct early in Carboniferous time, or shortly before its opening.

Lung-fishes continue their existence in the fresh-waters of the Carboniferous, and are known from their characteristic dental plates (Figure 33), incomplete skulls, and more or less complete remains. These are usually found in soft coal, associated with amphibians, and tell us that the dipnoans have not changed their habits of life since the great Coal Period.

The *Crossopterygians* (Figures 34, 35, 36) persisted from the Devonian throughout all subsequent geological time. There are a few genera and species known from the Carboniferous deposits, and a thin line carries the group to the present day, when the group is scantily represented.

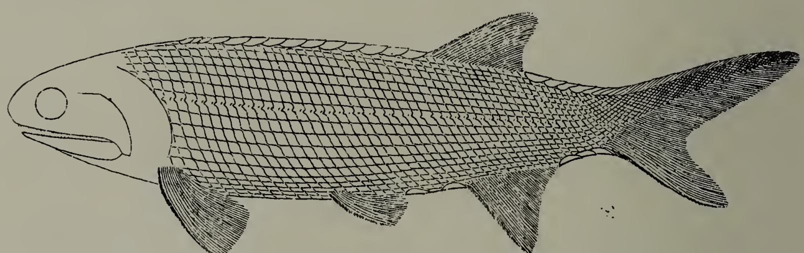

Fig. 42. Restoration of a primitive sturgeon, *Paleoniscus*, from the Carboniferous. After Lambe.

A family of enamel-scaled fishes, the *Paleoniscidae*, (Figure 42) began their existence in the Devonian as rather small fishes, and continued throughout the Carboniferous, to be represented today by the familiar sturgeons. An interesting item is the fact that in many places in Kentucky, Kansas and Iowa, heads of these fishes are preserved in small phosphatic nodules exhibiting in marvelous perfection the cartilaginous brain-box, the myodome,* the brain,† nerves, blood-vessels, eye, and other soft parts.

A single small species of the family Platysomatidae, known from the Coal Measures at Mason Creek, Illinois, seems to indicate the beginnings of the bony fishes which form such a diverse and abundant group among modern fishes.

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* Watson, D. M. S., 1925. The Structure of certain Palaeoniscids and the relationships of that group with other bony fishes. Proc. Zool. Soc. London, 815-870, 30 figs., 2 pls.

1928. On some points in the Structure of Paleoniscidae and allied fish. *Ibid.*, pp. 49-70, 15 figs.

† Moodie, Roy L., 1915. A new fish brain from the Coal Measures of Kansas, with a review of other fossil brains. J. Comp. Neurol., xxv:135-181, illus.

THE AMPHIBIANS AND REPTILES OF THE GREAT COAL PERIOD

There are no known remains of land vertebrates, tetrapoda, from the Carboniferous of Indiana itself, but in the adjoining states of Illinois, and especially in eastern Ohio and in Pennsylvania hundreds of incomplete skeletons of small early land vertebrates have been discovered in the cannel coal, and in nodules contained within the shales. None of these tetrapods of the Coal Period exceeded five feet in length and the great majority of them were less than a foot in length. Two species less than two inches long are known from the Mazon Creek, Illinois, shales. No new discoveries of Carboniferous amphibians have been made for many years, and much remains to be learned of the anatomy of the one hundred species so far described from the Coal Measures.* Two species are very fully known, even to some of the soft parts, but the fauna is known largely from fragments.

The science of *Ichnology*, the study of fossil footprints, has added a great deal to what we already knew about the tetrapods of the Coal Period, but so far no one has been able to correlate footprints with species known from skeletal remains. Ichnology is of importance in enabling us to learn a little of the activities of some of the creatures of the Coal Period. They tell us something of the size of these earliest land vertebrates which we would not otherwise know. Enormous tracks, nearly as large as those of the elephant, are known from Kansas, and tiny tracks elsewhere give the range in size and but little else. One trackway (Figure 43) of a Carboniferous tetrapod, as he walked along the wet sandy shore, will suffice to show their nature.

The amphibians of the Coal Period may be divided into two great groups, called the Branchiosauria and the Microsauria. A third group, the Salientia or frogs, is indicated by a single specimen, *Pelion lyelli*, (Figure 45) from the Ohio Coal. A similar distribution of type is shown by the Carboniferous species known from Europe, and the species of the two hemispheres are so similar that paleontologists think there must have been a community of origin of these small swamp dwellers. A migratory pathway must have existed during early Carboniferous times across the northern Atlantic, to explain the known distribution of the fossil faunas of the American Coal Measures.

The Branchiosauria (Figure 44) were the ancestral salamanders, and like modern salamanders, were largely aquatic, though capable of living in damp localities, acquiring their supply of oxygen either by pulmonary respiration, or by aeration through the walls of an expansive pharynx. Doubtless they fed on small animals and especially on minute aquatic plants. The group lived the greater part of their lives in shallow fresh-water pools or lagoons, in swampy areas filled with plant growth to the extent of furnishing material for the huge coal beds of the period. These ancient salamanders occur in some numbers in Carboniferous rocks of western Europe, but in America there are only a very few small species found in Mazon Creek, Illinois, nodules.

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* Moodie, Roy L., 1916. The Coal Measures Amphibia of North America. Publ. 238, Carnegie Inst. Wash., pp. 1-222, illus.

Fig. 43. Footprints of a land vertebrate (amphibian?) from the Lyons sandstone of Colorado (Coal Measures), showing nature of feet of an animal which is otherwise unknown. The subject of Ichnology yields important and interesting, but unsatisfactory, results. Similar tracks are known from Ohio and in the Permian of Arizona. Photograph by Henderson.

Fig. 44. Restoration of an American branchiosaur, *Micrerpeton caudatum* Moodie, based on a very complete material showing form of body, pigment of eye, impressions of skeleton, lateral line organs, tail membrane and in a related species the impress of the liver and form of the entire alimentary canal. Length of fossil slightly less than two inches. Type from the Mazon Creek shales, Illinois, preserved in Walker Museum, University of Chicago. This animal was one of the ancestors of our modern salamanders.

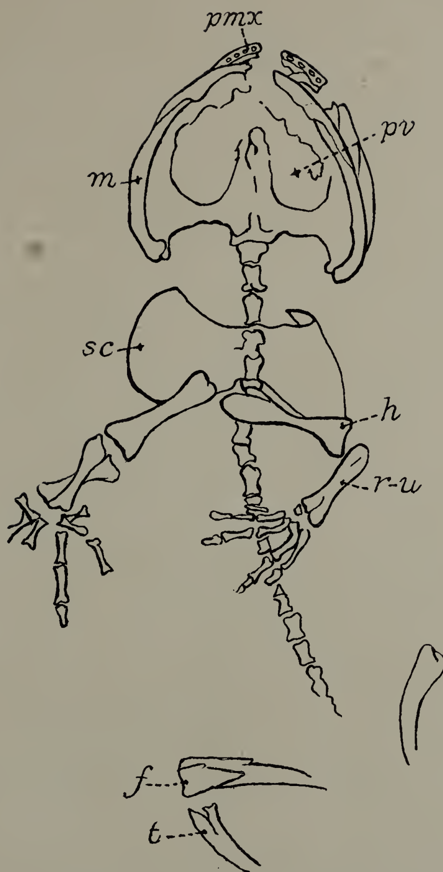

Fig. 45. A possible ancestor of the modern frogs, known as *Pelion lyelli* Wyman, from the Coal Measures of Ohio. The various skeletal parts are characteristic of the frogs.

h, humerus; m, mandible; pmx, premaxilla; pv, palatine vacuity; r-u, radius-ulna, conjoined; f, femur; sc, scapula; t, tibia.

On account of their habit of life the branchiosaurs had retained certain structures which are thought to be present only in fishes. Small cycloid scales covered the body, and in the skin of the sides of the body and on the head were present sensory organs of the lateral line system which enabled them to beware of danger because the lateral line organs were capable of perceiving slow wave vibrations. Otherwise they were deaf. Large eyes placed on top and sides of the head probably made perception by sight very good. The position of the eyes indicate that the branchiosaurs were bottom feeders, although the ventral surface was protected by intramuscular rods of cartilage. On top of the head, too, there is that remarkable perception organ—the pineal eye, functioning as heat perceptor. This organ is well developed in all Coal Meas-

ures vertebrates in which the head is well preserved. The creatures were voiceless, and were totally unable to protect themselves, except by hiding, and choosing quiet ways of living. They were timid, retiring adventurers in the world of life, but we believe they are the ancestors of our modern salamanders.

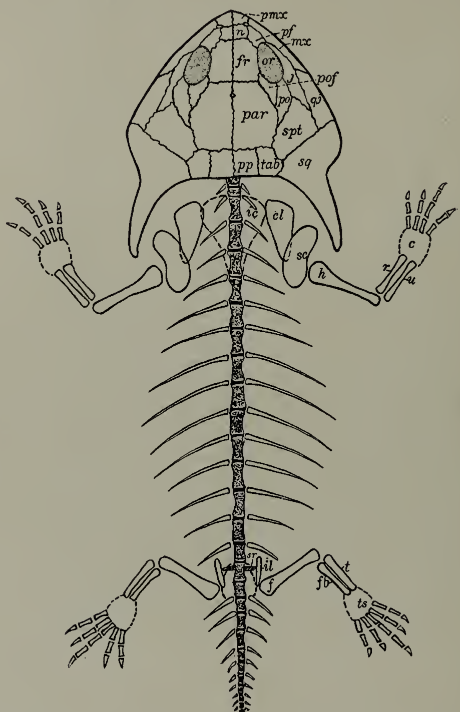

Fig. 46. Restoration of one of the small (about six inches long) reptile-like amphibians known as the Microsauria. The presence of horns was common to microsaurians of Europe and America (Ohio). c, space for cartilaginous carpus; cl, clavicle; f, femur; fb, fibula; fr, frontal; h, humerus; il, ilium; ic, interclavicle; j, jugal; mx, maxilla; n, nasal; or, orbit; pf, prefrontal; par, parietal; pmx, premaxilla; po, postorbital; pof, postfrontal; pp, postparietal; qj, quadratojugal; sq, squamosal; spt, temporal; sc, scapula; sr, sacral rib; tab, tabulare; t, tibia; r, radius; u, ulna; ts, tarsus. Based on material preserved in the United States National Museum.

The Microsauria were the active, reptilian, pugnacious vertebrates with a way to make in the world, and they made it. Representative microsaurians are found abundantly in western Europe, in Nova Scotia and in Ohio—a distribution difficult to understand. Many small groups of creatures are comprised in the order called Microsauria. They may have survived until near the close of the Permian (Figure 46), but their life was largely lived during the Carboniferous. There has been a suggestion that the Microsauria were ancestors to all of the reptiles, but the probabilities are that the reptiles and the microsaurians were derived from the same stem, a primitive group at present unknown.

Fig. 47. Map of North America showing localities where amphibians have been found in the Coal Measures.

We are sure that the microsaurian fauna as known from the Coal Measures are the diversified results of a long preceding line of evolutionary groups, of which we know nothing. The Microsauria were extremely specialized, showing Nature's efforts to attain a successful condition. Some of them, *Ptyonius*, were quite snake-like with the bodily parts reduced to a slender, elongate vertebral column, a head and small pectoral plates. Some, *Hylonomus*, were quite lizard-like, with small sharp claws and active bodies, finding their easy mode of life within the forests of sigillarians, totally removed from an aquatic habitat. Others, broad and squat, lived a stupid existence along the water's edge, while some, with long vertically flattened tails were expert swimmers. Such diverse modifications had been attained before the Coal Period, since these types are common alike to Ireland and Ohio.

The frog group, the Salientia (Figure 45), is represented, or rather suggested, by a single incomplete specimen, named *Pelion lyelli* by Wyman. This is an imperfect skeleton picked up three-quarters of a century ago from the mine dump in eastern Ohio. Among the hundreds of skeletal parts subsequently collected not a fragment can be assigned to this species. *Pelion lyelli* has the broad flat head of a frog with large

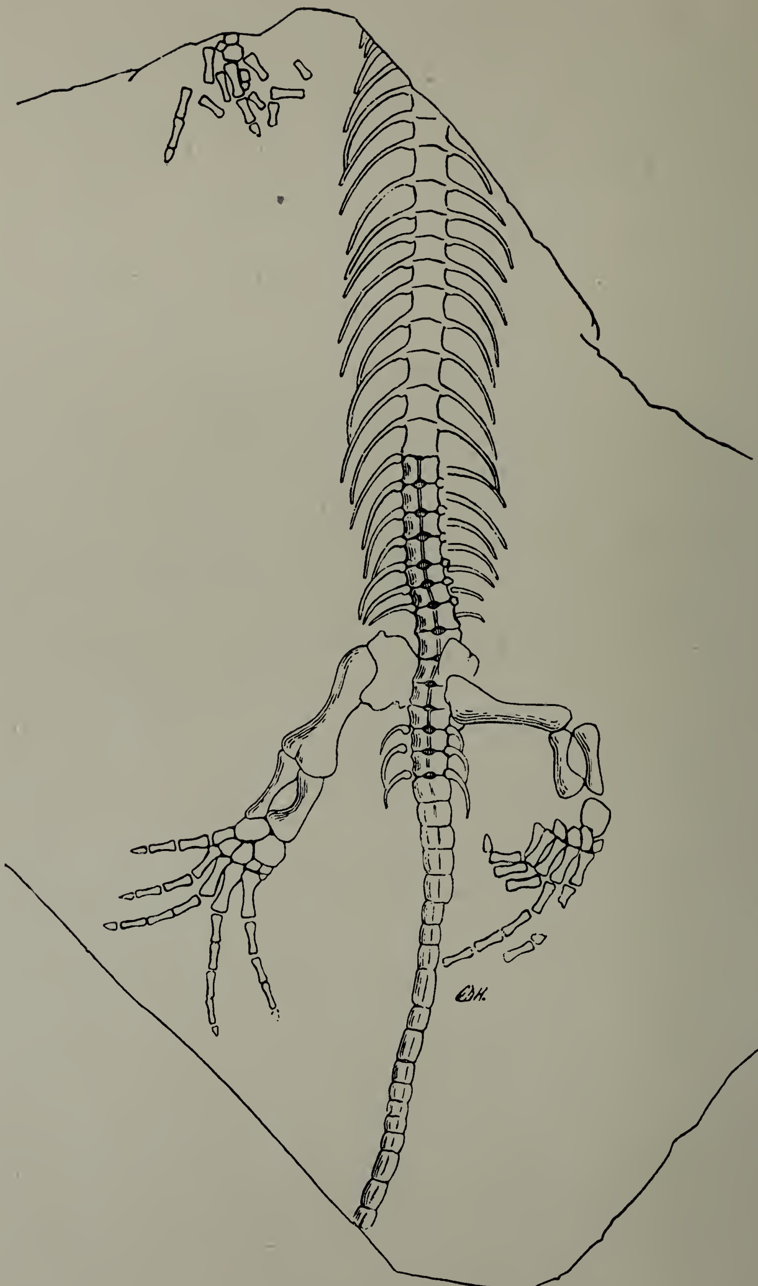

Fig. 48. Outline drawing of the skeletal parts of the "oldest known reptile," *Eosauravus copei* Williston, from the Coal Measures of Ohio. Specimen in U. S. National Museum. About natural size.

palatine vacuities: short, squat, heavy fore limbs, with radius and ulna fused, as in modern frogs: with long hind legs, though incomplete. The skeleton furnishes a suggestive picture of an ancestral frog, and as such we shall regard it until something more of its structure is known. No European species resembles it in any way.

The true reptiles are indicated by a single incomplete skeleton (Figure 48) from the Coal Measures of Ohio, designated as *Eosauravus copei* by Williston. A detailed account of this species* reveals many specialized features of which we do not now know the origin. The important characters of the cranium are unknown, because the body is broken at the neck, but the remainder of the skeleton reveals microsaurian characters of the greatest interest. The creature was about six inches in length, and lived an aquatic or subaquatic life, if we interpret the broad osseous tarsus and foot correctly. If we could learn more of the structure of the group of reptiles to which this species belongs, we would be in a fair way to understand the transition from the microsaurian Amphibia to the reptiles, for assuredly *Eosauravus* partakes of the qualities of both groups.

An important characteristic of nearly all the Paleozoic Amphibia is the presence of a ventral armature of cartilaginous or even osseous rods, embedded in the abdominal musculature, in the myocommatous septa. This is lacking in *Eosauravus*, but this is of no especial consequence since the character is an extremely variable one. Among some of the Permian species the ventral chevrons formed a veritable armature.

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* Moodie, Roy L., 1909. Carboniferous air-breathing Vertebrates of the United States National Museum. Proc. U. S. Natl. Museum, vol. 37, pp. 11-16, plates 4 and 5.

PERMIAN VERTEBRATES IN THE NEIGHBORHOOD OF INDIANA

The Permian witnessed the closing of the Paleozoic, and it was marked by widespread arid climates and saw vast changes in the nature of the vertebrates. During this period the stem groups of the birds and mammals were evolved, many archaic forms became extinct, and bizarre forms arose and passed away. The period has been studied especially by Williston, Case,* Cope, and others. The rocks of the period throughout the world are predominantly red, and the term Red Beds has come to indicate the Permian, although red rocks are known in other periods.

Fig. 49. Paleogeographic map of North America showing land and water during the lower Permian. Attention is particularly called to the small Permian localities on the east and on the west of Indiana. After Schuchert.

* Case, E. C., 1915. The Permo-Carboniferous Red Beds of North America and their Vertebrate Fauna. Publ. 207, Carnegie Institution of Wash.

The map (Figure 49) shows two small Permian localities, one in Illinois near the western Indiana line and the other in western Pennsylvania. Other deposits are known in West Virginia,* Kansas, Oklahoma, Texas (the most extensive deposits in America) and New Mexico.

The deposit on Salt Fork Creek in eastern Illinois, near Danville, is less than forty square feet all told. The writer was sent to this locality in 1907 by Dr. Williston to see if further material was to be found, but a week's excavation resulted in a mere handful of bones. Similar conditions doubtless exist in the Pennsylvania deposits† where fragments only have been discovered. The Kansas deposit is of small extent. These small fragmentary faunas are only to be understood‡ by reference to the more complete information derived from the deposits in Texas.

Fig. 50. A Permian reptile from the Red Beds of Texas. After Williston.

A glance at the nature of the vertebrate fauna of the Permian shows the startling physiographic changes which had been wrought during the close of the Paleozoic epoch. Fully two-thirds of the North American continent had emerged from the sea, never again to be so completely inundated. Epicontinental seas of slight depth did come up, during the Cretaceous, from what is now the Gulf of Mexico, but after the Paleozoic the land mass remained essentially what it is now. The influence of this change in environment is clearly seen on the vertebrates from the Permian.

Marine vertebrates are indicated by the eight species of sharks which are known and possibly other incompletely known species. Several lung-fishes of different genera indicate the fresh-water life, as do the scant remains of other fishes.

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* Tilton, John L., 1926. Permian Vertebrates from West Virginia. Bull. Geol. Soc. Amer., vol. 37, pp. 385-396, pl.

† Case, E. C., 1908. Description of vertebrate fossils from the vicinity of Pittsburgh, Pennsylvania. Annals Carnegie Museum, iv, 234-241, pl.

‡ Case, E. C., 1911. Revision of the Amphibia and Pisces of the Permian of North America. Publ. 146, Carnegie Inst. Wash. Also other volumes on Cotylosauria, Pelycosauria, etc.

Fig. 51. Where animals walked when the world was young. Footprints of an insect, to the right, and tracks of a small reptile-like amphibian, to the left, as seen on a slab of bright red (shown dark in the photograph) and gray (the lighter areas) shale collected on the north slope of Castle Peak, ten miles due south of Merkle, Texas. These fossil footprints are the tracks of one member of a new fauna, soon to be described from the Red Beds.

The land vertebrates, however, are the most significant and their diversity of structure indicates a rapidly evolving group from which later vertebrates were to arise. The nature of the evidence is that of thousands of petrified bones and footprints (Figures 50, 51). Skeletons of these early vertebrates, sufficiently complete for mounting (Figure 52) are preserved in Walker Museum, University of Chicago, at the American Museum of Natural History, at the Peabody Museum, Yale University, in the University of Michigan and elsewhere. These skeletons represent stegocephalian Amphibia; possibly salamanders and other diverse groups now extinct.

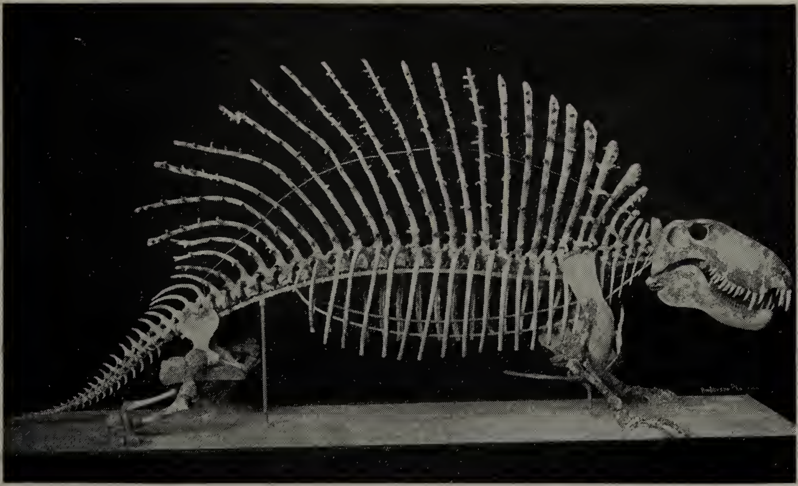

Fig. 52. Mounted skeleton of a Permian long-spined reptile in the American Museum of Natural History. Fragments indicate the presence of this, or a similar form, in the Indiana region.

The stegocephalians are of the greatest interest, and one form, *Eryops*, was almost as large as the Triassic labyrinthodonts. The anatomy of the skeleton is very completely known, and a mounted skeleton has been on exhibition for some time. Some of the fragments found in Pennsylvania are related to this large creature. A common peculiarity of the Permian amphibians was the roofed-over cranium, hence the term *stego-cephalian,* meaning roof-headed.

One of the species of Permian vertebrates found in the deposit at the Illinois-Indiana line was a curious creature called *Diplocaulus* (Figure 53). This animal has been fully described by Douthitt* in a posthumous paper edited by S. W. Williston. The shape of the skull, drawn out into long horns, is extremely odd (Figure 53) even in a fauna of many curious forms. The vertebral column was long and slender, and the limbs were very weak. Douthitt regards the animal incapable

* Douthitt, Herman, 1917. The Structure and Relationships of Diplocaulus. Contributions from Walker Museum, vol. 11, no. 1, pp. 1-41, 2 plates, 6 figures.

Fig. 53. Skull and jaws of a peculiar Permian vertebrate, *Diplocaulus*, from the Red Beds of Texas.

of moving on dry land, nor could it have lifted its head out of an aquatic medium, where it was doubtless a bottom feeder, rising at intervals to the surface of the water to gulp air.

The reptiles (Figure 52) were the highest vertebrates of the Permian, and the group is represented by scores of species.† When we consider the few (possibly only one) species of reptiles which are known from the great Coal Period, we may well be surprised at the vast expansion of Reptilia during the dry, warm Permian. We do not yet know the progenitors of all of the Permian reptiles, but we are sure that most of the diverse groups became extinct before the opening of the Triassic. Case* has reviewed the evidences of conditions under which the Permian reptiles lived. The land life of the period came suddenly and completely to an end in North America. Where the species came from and why they disappeared are among the many unsolved problems of paleontology.

† Williston, S. W., 1914. The Age of Reptiles in "Water Reptiles of the Past and Present." Chicago, Chapter IV. American Permian Vertebrates. Chicago. Osteology of the Reptiles. Cambridge. Papers in Journal of Geology.

* Case, E. C., 1919. The Environment of vertebrate life in the late Paleozoic in North America: a Paleogeographic Study. Publ. 283, Carnegie Institution of Washington.

TRIASSIC VERTEBRATES IN EASTERN STATES AND IN THE FAR WEST

The series of deposits of Mesozoic and Cenozoic age, elsewhere enormous, are entirely wanting in Indiana. This is due to the imperfection of the geological record. While the surface of what is now Indiana was above water from the close of the Coal Measures to the present time no water-borne deposits were accumulated. Whatever river deposits or lake sediments may have accumulated in Indiana during these long periods of time were either eroded or covered by the vast amount of glacial material brought in during the great Ice Age. Such being the case, and in order to complete our picture of vertebrate development, it is necessary for us to look elsewhere for evidences of Triassic vertebrates.

Fig. 54. A Triassic landscape with a long-snouted phytosaur in the foreground, and a characteristic labyrinthodont behind. The phytosaurs were crocodile-like in appearance, but more like the dinosaurs in structure. The nostrils were placed immediately in front of the eyes. The group is known exclusively from the Triassic. After Williston.

In the eastern states of New Jersey, Massachusetts, Connecticut and Pennsylvania occur the Newark series of rocks, of Triassic age, which bear abundant evidences of the vertebrate life of the times. In the far western states of Wyoming, New Mexico and Texas occur Triassic deposits containing remains of upland and semi-aquatic vertebrates. Marine Triassic deposits containing aquatic reptiles otherwise and elsewhere unknown, and which are of the greatest interest, are found on the Pacific Coast.

Fig. 55. A group of small Triassic dinosaurs.

Triassic fishes have long been known in abundance* from the Newark series and the general account of fish development is known.†

The amphibians of the Triassic were the huge, unwieldy labyrinthodonts which were worldwide in distribution and which became totally extinct before the close of the period. Their heavy heads are found in Pennsylvania, Wyoming** and Texas.†† These creatures were the terminal forms of a long line having their origin in the early Carboniferous.

The subject of *Ichnology*, the study of footprints, was founded on an attempted interpretation of tracks found in the Triassic rocks of the Newark series. A large number of species have been named and numerous attempts have been made to correlate footprints and skeletal remains.‡

The reptiles of the Triassic were of an expanding plastic type and they foreshadowed the coming of later groups. Dinosaurs (Figure 55) of small size and active habits occur in the Triassic rocks where their remains are associated with those of phytosaurs and labyrinthodonts.¶ In the deposits of Wyoming|| occur several species of phytosaurs (Figure 54). The marine triassic rocks of the Pacific coast carry remains of ichthyosaurs§ of a primitive type.

Mammals and birds are unknown during Triassic times, although mammal-like reptiles occur in foreign deposits.

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* Eastman, Charles R., 1904. The Triassic Fishes of New Jersey. Geol. Surv. N. J., Rept., pp. 29-102, 14 plates.

Eastman, Charles R., 1911. Triassic Fishes of Connecticut. Bull. 18, Geol. Surv. Conn., pp. 1-75, 11 pls.

† Eastman, Charles R., 1912. Mesozoic and Cenozoic Fishes. Bull. Geol. Soc. Amer., vol. 23, pp. 228-232.

** Branson, E. B., 1905. Structure and Relationships of the American Labyrinthodontidae. Journ. Geol., xiii, pp. 568-610, figs. 1-19.

†† Case, E. C., 1922. New Reptiles and Stegocephalians from the Upper Triassic of western Texas. Carnegie Inst. Wash., Publ. No. 321.

‡ Lull, R. S., 1915. Triassic Life of the Connecticut Valley. Bull. 24, Geol. Surv. Conn., pp. 1-285, 124 figs.

¶ Huene, F. von, 1921. Reptilian and Stegocephalian Remains from the Triassic of Pennsylvania in the Cope Collection. Bull. Amer. Mus. Natl. Hist., xliv, 561-574, illus.

|| Mehl, Maurice G., 1915. The Phytosauria of the Trias. Journ. Geol., xxiii, 129-165, 20 figs.

§ Merriam, John C., 1908. Triassic Ichthyosauria, with special reference to the American forms. Mem. Univ. Calif., Vol. 1, pp. 1-196, 18 plates.

Fig. 56. Skeleton of a small flying reptile, pterodactyl, *Pterodactylus micronyx* H. v. Meyer, from the Jurassic lithographic slates of Bavaria. Somewhat reduced. After Broili.

ADVANCEMENT OF THE VERTEBRATE GROUPS DURING THE JURASSIC AND COMANCHIAN IN AREAS OUTSIDE OF INDIANA

The greatest advances made in vertebrate life with the opening of the Jurassic were those concerned with the origins of the birds and mammals. Nowhere in America is the vertebrate life of the Jurassic pictured so clearly as it is in the lithographic slates of Europe.* Creatures otherwise unknown are preserved in startling perfection (Figures 56, 57). The following list of papers will be of service to those seeking further information:

Fig. 57. The Jurassic, reptilian bird whose remains occur in the slates of Solenhofen, Europe. The bird was the size of a crow. A pterodactyl is in the air beyond the birds. After Berry.

Osborn, H. F. 1915. Close of Jurassic and Opening of Cretaceous time in North America. Bull. Geol. Soc. Amer., vol. 26, 295-302.

——— and Mook, C. C. 1919. Characters and Restoration of the sauropod genus Camarasaurus Cope. Proc. Amer. Philos. Soc., lviii, 386-396, 3 figs.

Schuchert, Charles. 1918. Age of the American Morrison and East African Tendaguru Formations. Bull. Geol. Soc. Amer., vol. 29, 245-280.

Lee, Willis T. 1915. Reasons for regarding the Morrison an introductory Cretaceous Formation. Ibid., vol. 26, 303-314.

* Berry, Edward W., 1918. The Jurassic Lagoons of Solnhofen. Scientific Monthly, October, 361-378, 5 figs.

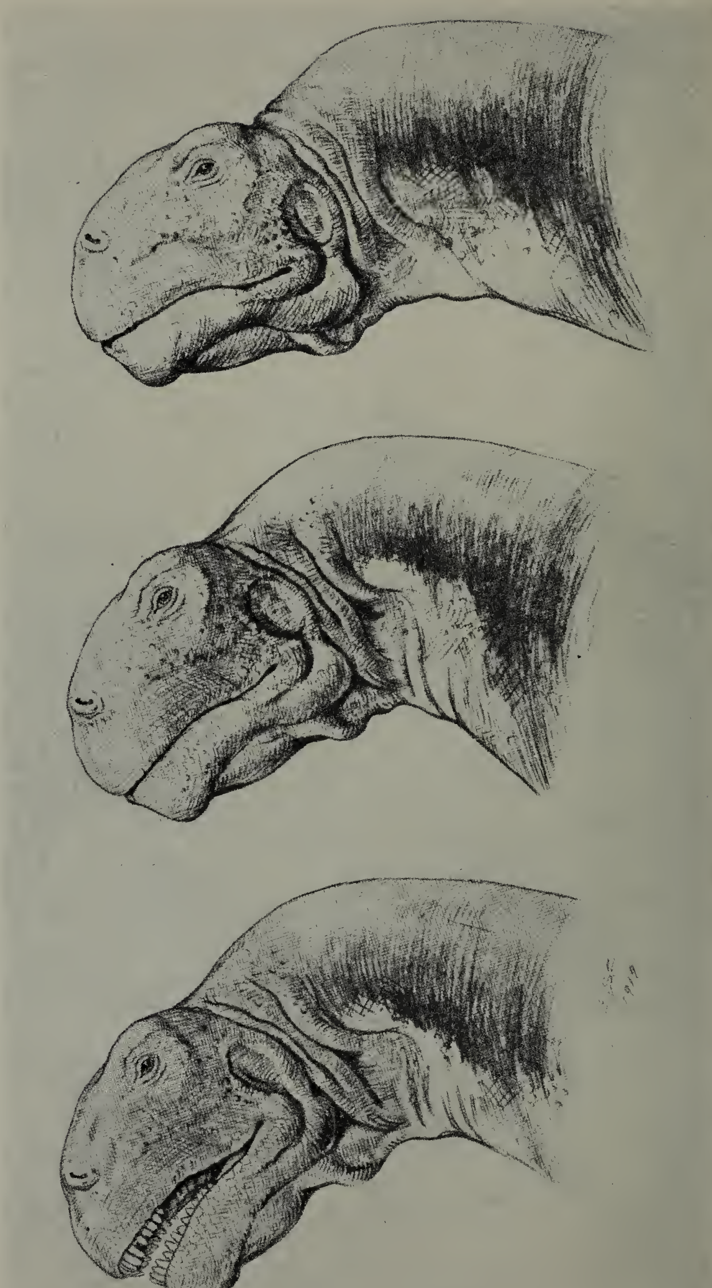

Fig. 58. Three studies of the head of a sauropod dinosaur, *Camarosaurus*, by Osborn and Mook, based on material in the Cope Collection in the American Museum of Natural History.

A, head extended and bent upwards. B, neck flexed and head bent downwards. C, neck flexed and head bent strongly downwards to show ground-feeding pose and to expose the teeth. This creature was one of the gigantic, quadrupedal, upland dinosaurs.

Lull, R. S. 1915. Sauropoda and Stegosauria of the Morrison of North America compared with those of Europe and eastern Africa. Ibid., vol. 26, 323-334.

The archaic mammals of the time were small creatures, a few inches in length, incompletely known, and all the known forms appear to belong to the primitive group Multituberculata, and all were probably egg layers.

THE VERTEBRATES OF THE GREAT CRETACEOUS INLAND SEAS

The land and water areas, all represented far away from Indiana, of the long Cretaceous period acquired sediments in which all of the vertebrate groups have been found. It will be convenient to regard the land areas as those bordering on the great inland Cretaceous sea which at one time connected the waters of the Arctic Ocean with those of the Gulf of Mexico. Deposits over 20,000 feet thick indicate the depth of the water and the duration of the period.

The fishes of the Cretaceous had lost nearly all of their archaic features and in general approach the structure of modern fishes, rather than the curious piscine forms we have been considering. There are no striking peculiarities about the Cretaceous fishes. They range through the sharks, chimaeroids, ganoid and bony fishes which after slight modifications gave rise to the aquatic vertebrates of today.

Amphibians are practically unknown from Cretaceous deposits, although frogs are known from the Jurassic. A salamander is indicated by scant remains, and it may be that the amphibians of the time were frogs and salamanders, as today.

The reptiles present an astonishing array (Figures 60, 61) in the air, in the water and on land. It will be profitable to review here some of the more important reptilian groups to show the extreme diversity of form, size and habitat.

Fig. 59. The large, flightless, toothed, diving bird, *Hesperornis*, whose bones are found in the Cretaceous chalk of Kansas, pursuing a bony fish in the waters of the Niobrara Sea. After Lucas.

Fig. 60. An idealized, Cretaceous landscape, in western Kansas. A toothed diving bird and a long-necked plesiosaur in the foreground. Pterodactyls on the cliffs and in flight. A mosasaur attempting to capture a small flying bird, and two plesiosaurs in the background. After Williston.

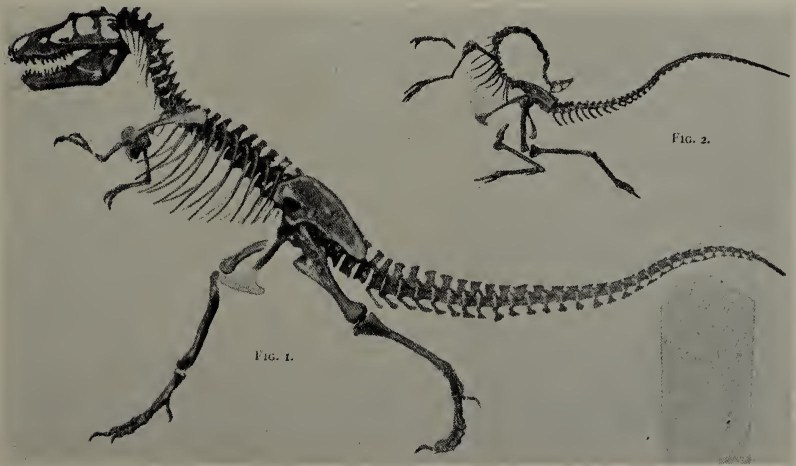

Fig. 61. Cursorial dinosaurs from mid-Cretaceous rocks of Canada. Fig. 1—*Gorgosaurus* a carnivorous dinosaur. Fig. 2—*Struthiomimus* a toothless, browsing, bipedal dinosaur, an offshoot from the carnivorus group. The skeleton is in the opisthotonic attitude as assumed during rigor mortis. After Osborn.

Turtles had arisen, somehow, during the early Cretaceous or Morrison, and in the upper Cretaceous show a diversity of form and size. One species from the chalk beds of Kansas attained a width of 12 feet across the front flippers.

Land lizards appear during the Upper Cretaceous but are scantily represented. The lizard group, however, the Sauria or Squamata, are represented by the large aquatic mosasaurs (Figure 60, background to right). These water reptiles attained a world-wide distribution, reaching a body length of forty feet. They are best known from the chalk beds of Kansas where thousands of specimens have been collected.

The Cretaceous crocodiles differed somewhat from the modern saurians. A few species were quite large, but none is very fully known.

A group of aquatic reptiles called the plesiosaurs were restricted to the Cretaceous. Their long, slender necks are characteristic of some of the members of the group (Figure 60), but some of them had short necks.

Flying reptiles called pterodactyls (Figure 60) are found associated with the marine reptiles in the chalk. Some of these volant saurians, with a wing expanse of 22 feet and a body weight of not more than 20 pounds, were the most highly adapted to life in the air of any of the pre-Tertiary vertebrates.

Dinosaurs of several types represent the land vertebrates (Figure 61). The dinosaurian reptiles of the Cretaceous were extremely diverse in structure and habit. They reached their maximum of expansion during this period and all of them became extinct at the close of the Cretaceous.

Birds of several types are known. One, a highly specialized wingless, toothed, diving bird (Figure 59) was the largest bird of the period. It was practically helpless on land. Another toothed bird, with strong wings, was about the size of the modern pigeon.

The Cretaceous mammals were all small, so small that the desert ants bring their teeth to the surface in their vast tunneling operations. It has been frequently suggested that these small creatures by feeding of dinosaur eggs brought about the extinction of that group of reptiles. The mosasaurs which may have laid eggs, and the plesiosaurs which gave birth to living young were immune to such attacks, yet neither group survived the Cretaceous.

MAMMALS OF THE TERTIARY OF NORTH AMERICA

Attention is directed particularly to the *mammals*, not because fishes, amphibians, birds and reptiles are unknown, but because the Tertiary was the *Age of Mammals*, during which, in areas outside of Indiana, surprising developments took place. We find mammals attempting life in the sea, in the trees, in the air, in holes in the ground, on upland grassy plains, in marshes, in forested areas and other habitats. They were extremely diversified as to structure, size and bodily proportions. Nature was reaching out in every conceivable direction to determine successful lines of mammalian development.* Since it is not possible in this paper to even outline the progress the mammals made during the Tertiary, I am showing, in the figures, the normal evolutionary sequences in the horses (Figure 62); a bizarre, extinct, unsuccessful, clawed, ungulate mammal (Figure 63); a view across the high plains of Nebraska, with the camps of the bone diggers near one of the most remarkable deposits of Tertiary mammals known anywhere in the world (Figure 64); and the process of recovering fossil mammals for study (Figure 65). These will give the reader a slight conception of the enormous amount of skill and scientific work required to reach our present knowledge of Tertiary Mammalia.

THE PLEISTOCENE OF INDIANA

It will not be necessary for us to go into details of the Pleistocene geology of the state in this place. This has been done by Hay, whose writings are listed in the Bibliography. It is important to emphasize here the fact that following the close of the Paleozoic, in fact after the Coal Measures, fossil-bearing deposits do not exist in Indiana until we reach the Pleistocene beds from which an abundant and interesting mammalian fauna is known. The entire stretch of geological time throughout the vast Mesozoic and the Cenozoic, constituting 15% of the history of the earth, is not represented within the state limits of Indiana.

The determination of the faunal divisions of the deposits in Pleistocene times† need not enter into the present discussion except to point out that there are successive stages in the glacial and interglacial times during which the mammalian life is recorded. Since most of the Pleistocene mammals known from Indiana were herbivores it will be of interest to call attention to what little is known about the plants‡ of Pleistocene age which lived in Indiana. In a general way the plants were then very much as they are now. That is, there were woody trees, grasses and flowering plants. The distribution of plant life which served as food for the Pleistocene mammals was of great importance in determining the localities where the fossils are found, modified of course by water action of glacial rivers and lakes.

* Osborn, H. F., 1921. The Age of Mammals in Europe, Asia and North America. New York. pp. 1-635, 220 figures.

† Hay, O. P., 1912. The Recognition of Pleistocene Faunas. Smithson. Misc. Coll., 59, no. 20; 1-16, 10 maps.

‡ Knowlton, F. H., Plants of the Past. Berry, E. W., Tree Ancestors.

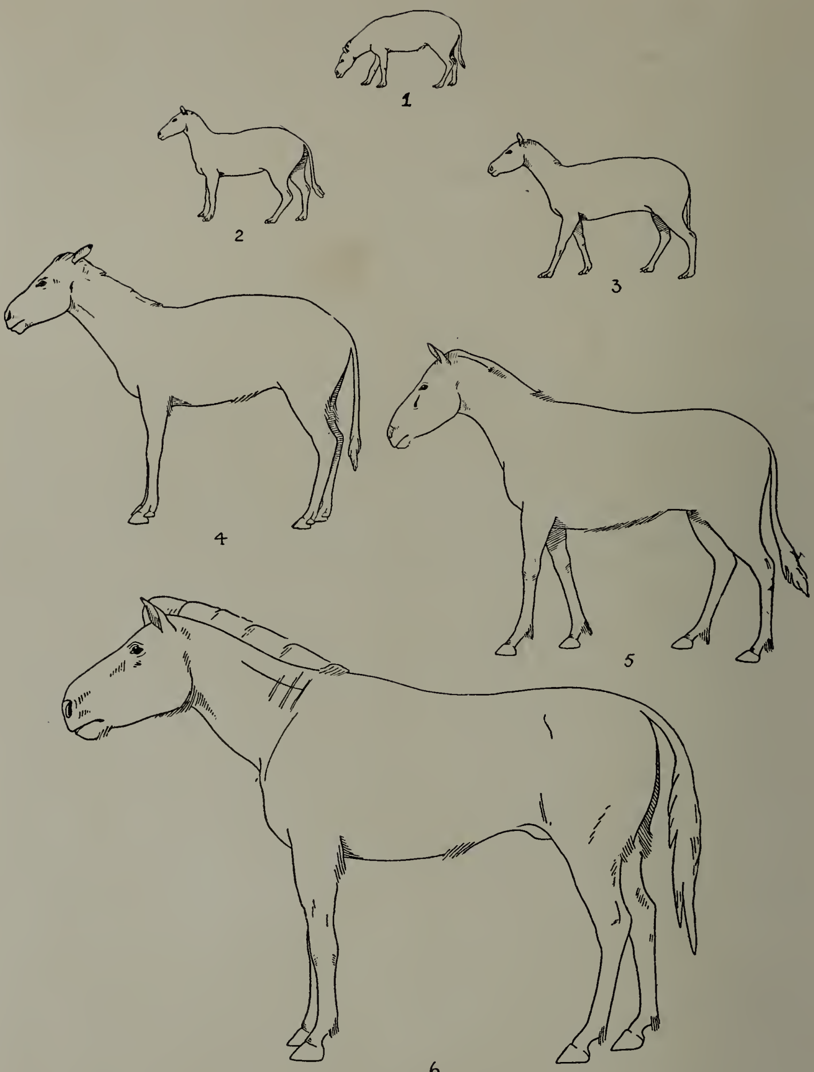

Fig. 62. Drawn to an exact scale, here reproduced less than one thirtieth actual size of animals. Sketch showing the evolution of the horses from the primitive four-toed ancestor to the last American horse prior to the extinction of the race. This series of drawings has been made on the basis of fossil remains of each of the forms in the Yale collection. The stages in development represented in the drawings are: Fig. 1. *Eohippus*, or Dawn Horse of Lower Eocene time, earliest of native American horses, four toes; Fig. 2. *Orohippus*, the mountain horse of Middle Eocene time, four toes; Fig. 3. *Mesohippus*, of Oligocene time, three toes; Fig. 4. *Merychippus*, of Miocene time, three toes; Fig. 5. *Pliohippus*, of Pliocene time, one toe; Fig. 6. *Equus scotti*, of Pleistocene time, the last of the native American horses, of which a nearly perfect specimen was collected by the Yale expedition of 1912. After Lull.

Fig. 63. The curious extinct mammal, *Moropus cooki* Barbour, from the Tertiary deposits of Nebraska, had a body like a tapir, with high shoulders; a neck and head resembling a horse; with three toed feet provided with hoofs so compressed and modified as to resemble claws, and possibly used as such in gathering together boughs of trees and tall grasses, or in tearing roots from the ground. Bones of this creature were found in abundance in a layer of rock near the top of a hill like the one shown in Figure 64. The *Chalicotheroidea* had a short geological history. After Barbour.

Figure 64. Camp of paleontologists on the high plains of northwestern Nebraska in the summer of 1908, near the Niobrara River, on the Agate Springs Ranch. Fossil-bearing rocks of Miocene age outcrop in the drainage channels and near the tops and along the sides of hills. The three tents to the left belong to the party from the American Museum of Natural History; to the left in the background the party from Amherst College; the University of Nebraska occupied the cabin; Yale University Museum to the extreme right and the Carnegie Museum party camped nearby. This was a notable gathering of a score of paleontologists. Photo by Thompson.

Fig. 65. In the block between the workers are skeletons of five oreodonts, small Miocene ungulates, in the hills in the background of Figure 64. When the block had been sufficiently excavated strips of burlap soaked in wet plaster were used to strengthen the rock so that the block could be turned and so removed to the Museum where the skeletons could be cleared of matrix. Photo by Thompson.

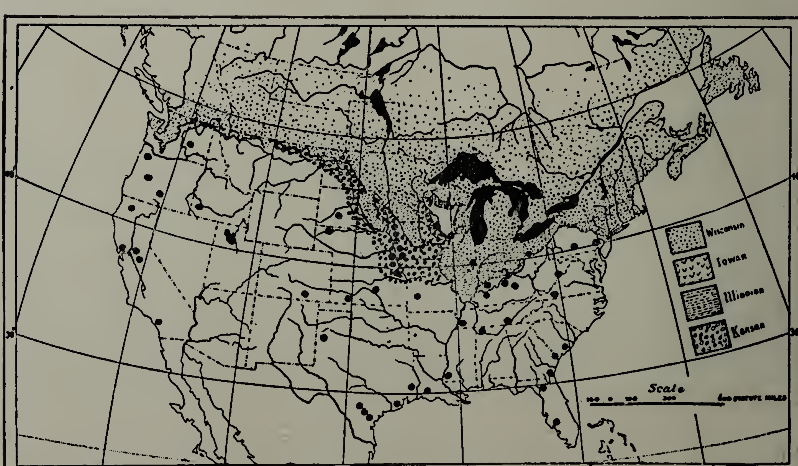

Fig. 66. Distribution of localities where remains of the Pleistocene great ground sloths have been found. There are three chief genera: *Megalonyx, Mylodon* and *Nothrotherium,* listed in a descending scale as to size. After Hay.

Fig. 67. General view of the left side of the giant Edentate, *Megalonyx jeffersonii*, shown in the attitude of browsing upon tree foliage according to the interpretation of Sir Richard Owen, following his deductions after a study of the skeleton. After Hay.

THE MAMMALS DURING THE GREAT ICE AGE IN INDIANA

The mammals of the Pleistocene of Indiana are very largely extinct, not only in Indiana, but throughout the North American continent. Among those now totally extinct throughout the world may be cited the giant edentates and the giant beaver. The musk-oxen found fossil in Indiana now live farther north. Their occurrence in Indiana indicates a far southern extension of their range during the Ice Age. Horses after living in North America for millions of years became extinct in the continent and were later reinstated after the Caucasian invasion.

Fig. 68. Left side of skull and jaw of *Megalonyx jeffersonii*, showing its massiveness. The diploic air-spaces were very extensive and served as adequate protection to the brain even after very severe injuries. Owen has described such an injury in great detail. After Hay.

Fig. 69. Front and hind feet of another ground sloth, *Myiodon robustus*, regarded as effective organs for undermining trees to secure the foliage. After Hay.

THE GREAT GROUND SLOTHS

This group of giant mammals, confined exclusively to the western hemisphere, were widely distributed throughout the United States (Figure 66). The general appearance of one genus is shown in the frontispiece. This same species lived in Southern California* and in the eastern states. Several more or less complete skeletons are known from the Rancho la Brea asphalt pits at Los Angeles. Stock's account* based on this material is the best and most complete discussion of the group which has ever appeared. Hay (see Bibliography) has written extensively of the association of these giant edentates with the other Pleistocene species discussed.

Only one species of this group, *Megalonyx jeffersonii* (Figure 67), has been found within the state. This was described by Leidy.

Fig. 70. A restoration of the American mastodon as it probably appeared in life. It has been stated that the body was clothed in rather long, deep-red hair, but there are some reasons to doubt this. After Lucas.

THE MASTODONS

Bones and teeth of the American Mastodon have been found in the unglaciated parts of Indiana as well as within the various accumulations of drift. Hay has recorded over fifty localities where mastodon remains have been found. These proboscideans ranged during the Pleistocene throughout the whole of the United States, British Columbia and

* Stock, Chester, 1925. Cenozoic Gravigrade Edentates of western North America, with special reference to the Pleistocene Megalonychinae and Mylodontidae of Rancho la Brea. Publication 331, Carnegie Institution of Washington, pp. 1-206, 117 figures, plates 1-47.

Fig. 71. The teeth of the American mastodon have high, sharply-defined transverse ridges, in sharp contrast to those of the mammoth (Figure 76). After Lucas.

Yukon Territory. The size was about the same as that of the living elephant. Traces of the skeletal parts of the animal exist throughout the many thousands of years during which the Pleistocene existed.

A complete skeleton of the American Mastodon, found in Miami County, Indiana, is mounted (Figure 72) in the Public Museum at Milwaukee. Another, slightly damaged by fire, is in the Joseph Moore Museum at Earlham College.

Fig. 72. *Mammut americanum.* Skeleton of a specimen found in Miami County, Indiana. Now in Public Museum, Milwaukee.

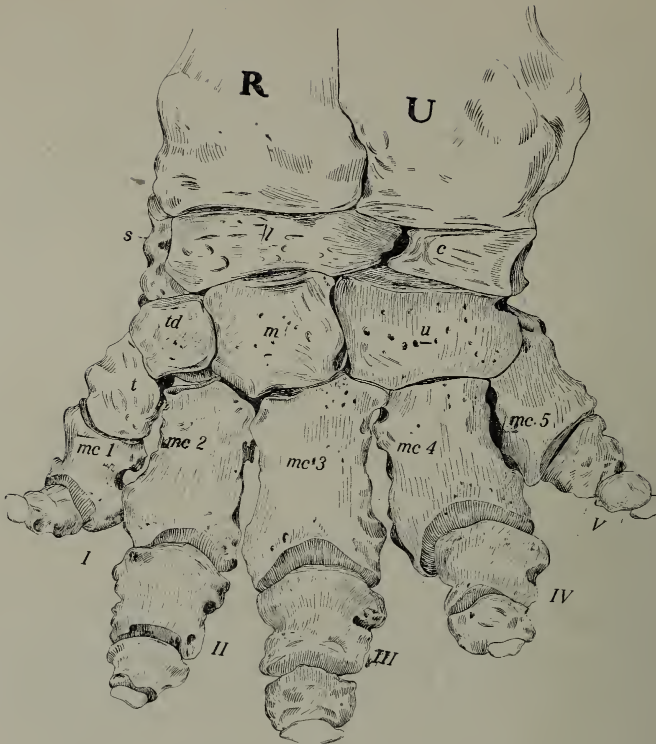

Fig. 73. *Mammut americanum.* Left fore foot seen from in front. R, radius; U, ulna; I, inner digit; V, outer digit; c, cuneiform bone; l, lunar; s, scaphoid; td, trapezoid; m, magnum; u, unciform; mc 1 to mc 5, the metacarpals.

The character of the teeth will immediately distinguish the mastodon from other proboscideans, the enamel plates being drawn up into sharp crests (Figure 71). The animal may have as many as twenty-four of these teeth from birth to old age, the teeth being discarded as rapidly as they cease to function in mastication. It is not possible, in all cases, to distinguish the mastodon by its tusks alone. In general the tusks are straighter than those of the mammoths.

The unsatisfactory evidences of the nature of the food of the Pleistocene mastodons indicates that twigs and foliage of conifers and other trees, the succulent flowering plants and certain mosses formed the diet of the Pleistocene mastodons, very much as the elephants of today. It is possible that the Pleistocene mastodons chewed up fairly large boughs and after extracting the juices spit out the woody pulp, as modern elephants are said to do.

FOSSIL ELEPHANTS

The best known species of all the fossil elephants is the hairy mammoth, *Elephas primigenius,* of which there have been about a dozen finds in Indiana. Its range was enormous, greater than that of any

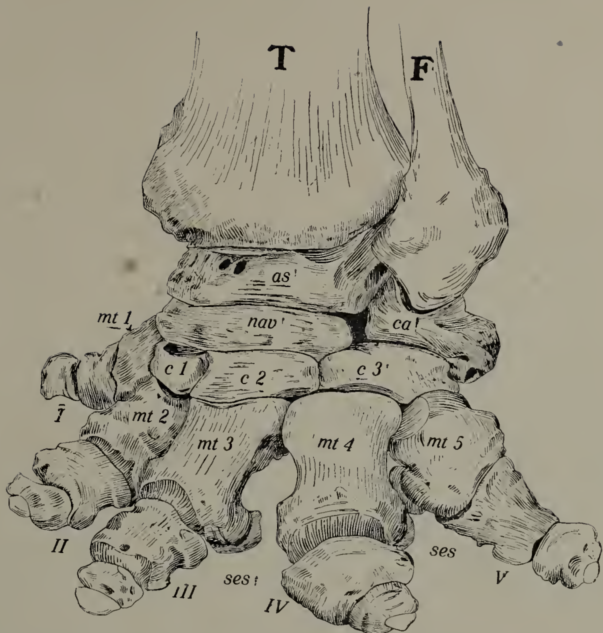

Fig. 74. *Mammut americanum.* Left hind foot, seen from in front. After Warren. *T*, the tibia; *F*, the fibula; *I*, inner digit; *V*, the outer digit; *mt 1* to *mt 5*, the metatarsals; *as*, astragalus; *ca*, calcaneum; *nav*, navicular; *cu*, cuboid; *c1*, *c2*, *c3*, the internal, middle, and external cuneiform bones; *ses*, sesamoids.

Fig. 75. A restoration of the hairy mammoth, *Elephas primigenius*, as it probably appeared in life. This species had an extremely wide range. This is the animal whose cadavers have been frozen in the Siberian marshes. After Lucas.

Fig. 76. The teeth of the mammoth are flat-crowned (compare with the Mastodon teeth, Figure 71). After Lucas.

other mammal that has not been distributed by man. Its skeletons and teeth have been found in Ireland and England, across the continent of Europe and Asia to Bering Strait, and from Alaska to the Atlantic Ocean and south over the glaciated regions to North Carolina. While its remains are abundant it is still infrequent when compared with the mastodon.

One of the most interesting discoveries in paleontology was the finding of the frozen cadaver of a hairy mammoth in 1901 on the banks of the Beresowka River, in eastern Siberia. The body was sufficiently

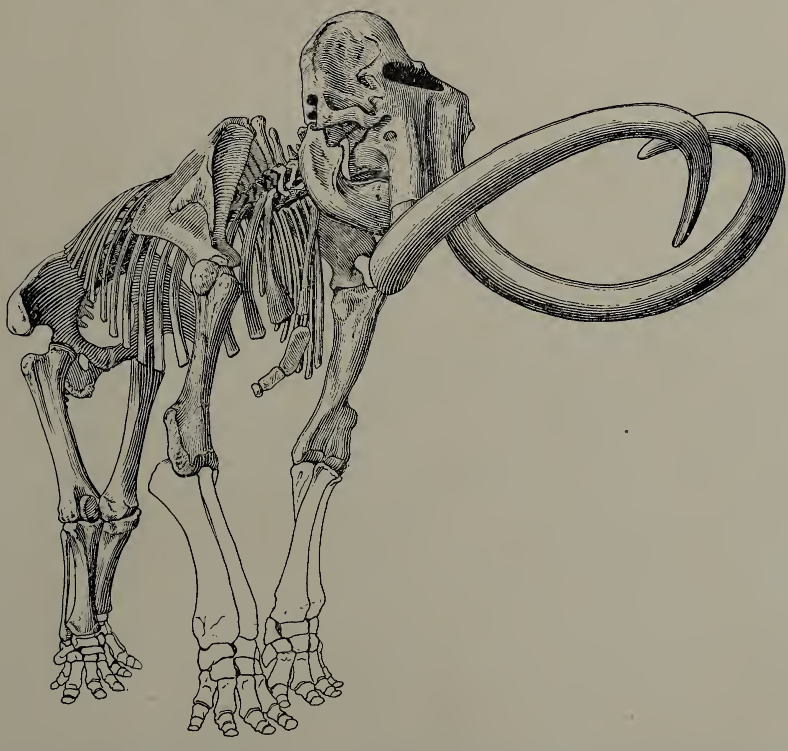

Fig. 77. Skeleton of the hairy mammoth, *Elephas primigenius*, found in Grant County, Indiana, and mounted in the American Museum of Natural History. After Hay.

well preserved for dissection. Three kinds of hair were found on the body, wool, hair and bristles, of a yellowish brown color. The tusk in one specimen had a length of over thirteen feet. The stomach of the Beresowka mammoth was filled with recently eaten food, composed of species of plants occupying that region today, indicating that the climate has not changed. Portions of cadavers have been found in Alaska, but the Indiana finds have all been bones and teeth.

Another species of mammoth, *Elephas columbi*, occurs as abundantly in the Pleistocene deposits as does the hairy mammoth, from which it is entirely distinct.

Many discoveries of skeletal remains of Pleistocene elephantids in Indiana cannot be identified for one reason or another. They indicate the relative abundance of these proboscideans within the state during the Pleistocene.

TRACES OF ANCIENT HORSES AND TAPIRS

Ancient and possibly extinct species of horses once ranged over Indiana, but traces of them are very rare. A neck joint found at Evansville possibly represents the species *Equus complicatus*. The bone was found associated with remains of extinct Pleistocene mammals such as the dire wolf, an edentate, a bison, a tapir and a deer. It is well known that the Equidae, or horse family, had their origin and went through an extensive development in America, over a period of millions of years (Figure 62), from the Eocene to the Pleistocene, only to become totally extinct and to have spread again over the entire area (Figure 78) after the coming of Europeans in the sixteenth century.

A single tooth represents the presence in Indiana of the extinct species of tapir, *Tapirus haysii.* Other modern species of the Tapiridae inhabit tropical America and tropical Asia. Fossil tapirs, however, occur in Europe and in North America.

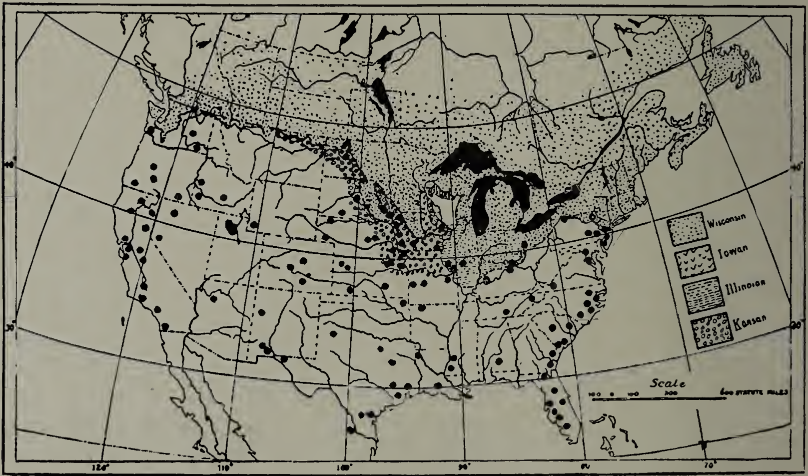

Fig. 78. Map showing localities where remains of fossil horses have been found in the United States and the relations of these localities to the various drift-sheets. After Hay.

PLEISTOCENE PECCARIES

The superfamily *Suoidea* contains the true pigs and the peccaries. Hogs are unknown from the Pleistocene, but remains of their relatives, the peccaries of the family Tayassuidae, are fairly abundant. Remains found in well-digging at a depth of 30 to 40 feet have been described from Indiana and Kansas, while other finds have been recorded from

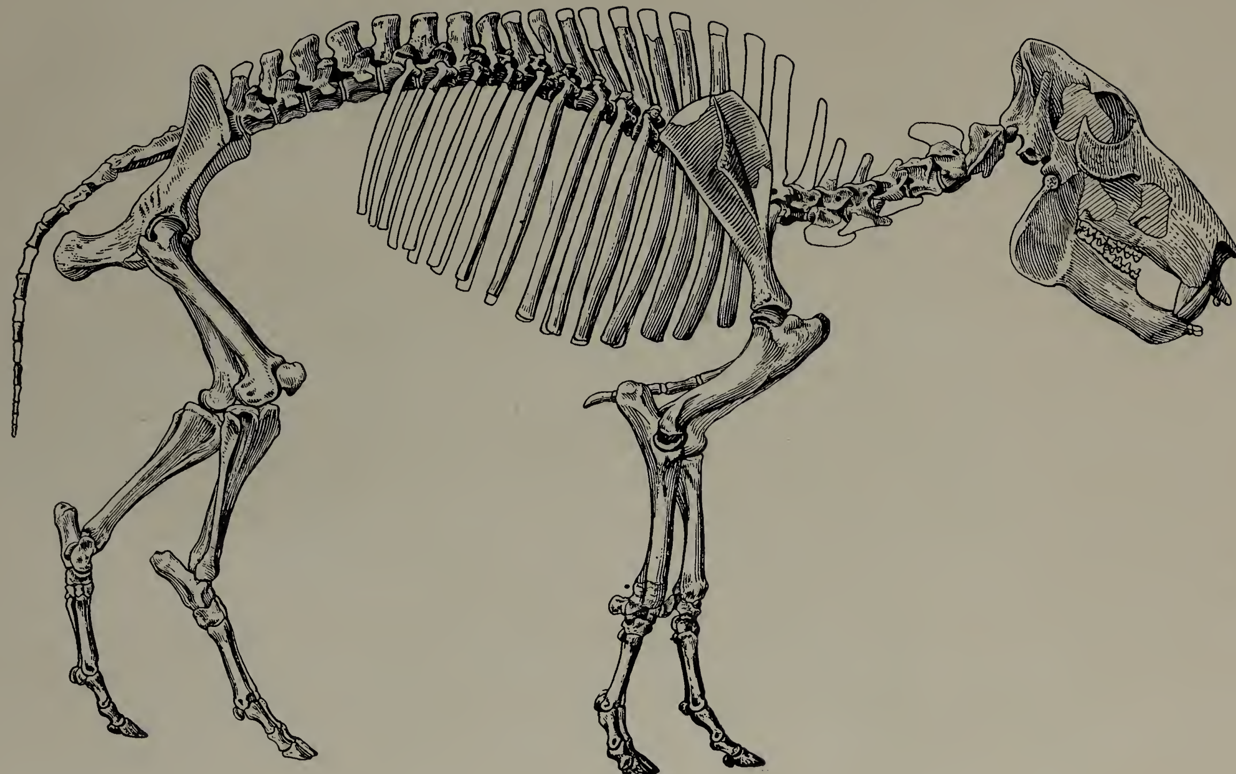

Fig. 79. A skeleton of the Pleistocene peccary, found in Kansas, as mounted in the American Museum of Natural History. *Platygonus leptorhinus.* After Hay.

fissures and caves. The fossil species are, in general, larger than the living peccaries found in southern United States south to Patagonia. Eighteen complete individuals were excavated in Ohio at a depth of 12 feet, in two groups, with noses all pointing the same way. The peccaries probably piled up to avoid the cold, as does the domestic pig, and were buried in a blizzard, or the caving in of the river bank. Similar conditions were found in the Kansas locality (Figure 79). A full account of this group as it occurs in Indiana is given, with abundant illustrations, in Hay's report (1912) on the Pleistocene vertebrates of the state.

Fig. 80. Side and front views of the fossil musk-ox, *Symbos cavifrons*, skull found at Hebron, Indiana, and now preserved in the American Museum of Natural History. About 1/6 nat. size. After Hay.

THE DEER FAMILY

The existence of members of the deer family, Cervidae, in Pleistocene deposits of Indiana indicates an antiquity for the Virginia deer, the elk, and possibly other species, which is interesting since it shows that the area has been congenial for the deer for many thousands of years. It is possible that the moose and the caribou ranged down into Indiana during the Ice Age but positive remains have not been identified. The confusion resulting from the difficulty of being sure of the exact age of the material, whether Pleistocene or Recent, renders the matter of the Pleistocene Cervidae unsatisfactory.

Fig. 81. Front and back views of the fossil skull of *Bison antiquus*, found at Vincennes, Indiana. After Hay.

MUSK-OXEN AND BISONS

The occurrence of the musk-ox, *Symbos cavifrons*, within the Pleistocene deposits of Indiana (Figure 80) is not at all surprising since it merely means that these creatures extended their present range southward during the extreme cold of the Ice Age. Specimens found within the state are preserved at Earlham College and the American Museum of Natural History.

Fossil bisons, of an extinct species, have been found within the state (Figure 81), but these animals had their chief habitat to the westward, and remains found in the eastern limits of their range are rare.

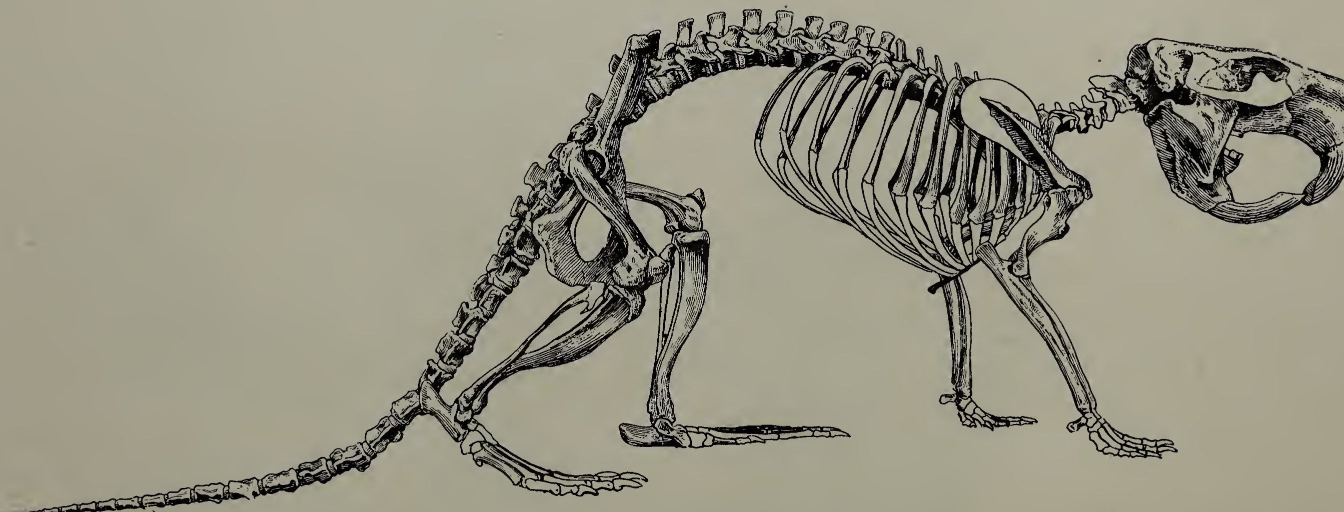

Fig. 82. The most complete skeleton of the giant beaver, *Castoroides ohioensis*, as mounted in the Joseph Moore Museum of Earlham College at Richmond. The length of this youthful individual is seven feet two inches. The remains were found in a swamp near Winchester. The skeleton was described and figured by Joseph Moore in the American Geologist, XII, 68-74, pl. xii, and in the Journal of the Cincinnati Society of Natural History, XIII, 138-169, 25 figs. It is further described by Hay in his Indiana report, 1912, pp. 755-768. After Hay.

THE GIANT BEAVER

The chief paleontological treasure of the Joseph Moore Museum of Earlham College, Richmond, is the mounted skeleton of the giant beaver, *Castoroides ohioensis*, first described from Ohio in 1838, found in excavating a canal. The skeleton referred to above was found in Dismal Swamp, Randolph County, Indiana. The giant beaver, attaining a maximum length of nine feet (Figure 82), belonged to the earlier phases of the Pleistocene and existed long after the disappearance of the ice. Numerous specimens have been found ranging from New York to the Great Plains and from Florida to Minnesota, as well as in Yukon Territory, nearly up to the Arctic Ocean. About a dozen finds of the giant beaver have been made in Indiana. The habits of the animal can only be conjectured from its skeleton, and this indicates habits similar to the modern beaver, which has a similar geological history, occurring in early Pleistocene deposits.

Fig. 83. The palate, showing full upper dentition, of a skull of the dire wolf, *Aenocyon dirus*, from the asphalt of Rancho la Brea at Los Angeles. Mature individual. *Courtesy of the Los Angeles Museum.*

THE DIRE WOLF

The type material for the species *Aenocyon (Canis) dirus,* the giant wolf of the Pleistocene (Figures 83, 84), based on incomplete parts was found in Indiana. The species is now very thoroughly known because of the abundant skeletal remains secured within recent years from the asphalt deposits at the Rancho la Brea. The Los Angeles Museum possesses more than 1,200 specimens—enough to prepare several hundred complete skeletons. The photographs (Figures 83, 84) are of a singularly complete skull and jaw in that Museum. In Indiana remains of this great wolf are associated with other extinct mammals.

Fig. 84. Crown view of the inferior dentition of the dire wolf, complete with the exception of the last right molar, and the incisors which had been loosened by pyorrhea. The jaw definitely belongs to the skull, an unusual occurrence since skeletal parts are usually separated in the asphalt. The evidences of pyorrhea are discussed in the "Annals of Medical History, X:199-201, 3 figs., 1928." *Courtesy of the Los Angeles Museum.*

A FOSSIL BEAR

An incomplete skull found in digging a well in Ohio seems to indicate the presence of an extinct bear, *Ursus procerus* Miller, found in glacial deposits. This species is the only bear known from the Pleistocene of the region about Indiana, except the *Ursus americanus.* The bear family is widely distributed, but none is known in America before the beginning of the Pleistocene. It will be of interest to note here the nature of the short-faced bear, *Arctotherium,* in California.* This paper contains an interesting discussion of the Pleistocene Ursidae and carries an extensive literature list.

Since the history of ancient human existence in Indiana and in the Western Hemisphere as a whole, totalling at the most only a few thousand years, is so brief, we must turn to the Old World for evidences of early man and the fossils of all the higher anthropoids (Gregory & Hellman, '26). It has long been thought that man originated near central Asia (Gregory, '27 a) and from that point spread abroad over the earth. Compared with other mammals man has shown an extreme degree of adaptation, so far as habitat is concerned. Groups of man now

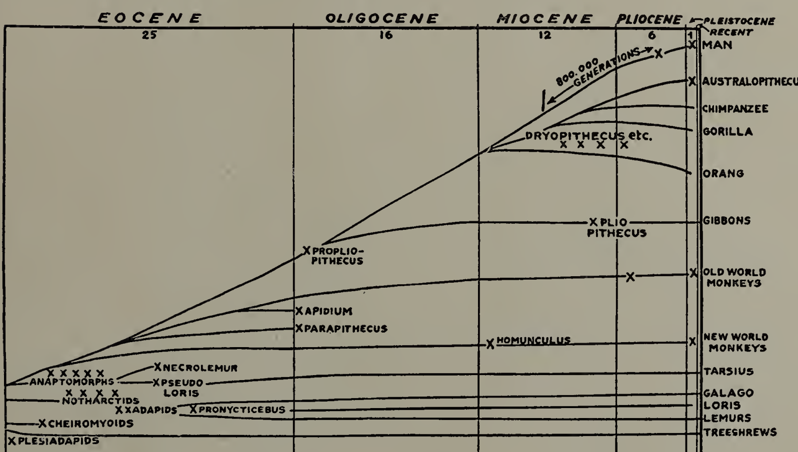

Fig. 85. Tentative Phylogeny of the Primates. After Gregory.

occupy every region on the globe, from the coldest to the hottest. High and low he has sought out and adopted many places where he might survive. There is no accepted paleontological evidence to show that man arose from the monkeys (Gregory, '27) or even from any known apes, but it seems certain that all the anthropoids, including both man and all the apes, had a common, but still unknown, ancestor (Figure 85) far back in geological time. This is one of the most interesting and important phases of research today, and all the evidences are being closely scrutinized.

Many years ago a surgeon in the Dutch army, then stationed at Java, discovered in a bed of river wash, from which Pleistocene mammal bones had been secured, the skull cap, limb bones and teeth of what is undoubtedly the oldest man-like form (Figures 86-88) for which the name *Pithecanthropus erectus* was proposed. These fossil bones have become extremely famous, in spite of the fact that the discoverer after publishing his memoir on them, refused for forty years to let anyone

* Merriam, J. C., and Stock, Chester, 1925. Relationships and Structure of the short-faced bear, Arctotherium, from the Pleistocene of California. Publ. 347, Carnegie Inst., Wash., pp. 1-35, 10 plates and five figures.

Fig. 86. Upper aspect of the skull cap of the oldest man-like form, *Pithecanthropus erectus* Dubois, from the river drift, Upper Pliocene or Lower Pleistocene, of Java; 500,000 years old. From Hrdlicka.

have access to the specimens in Haarlem, an attitude which he has recently abandoned. *Pithecanthropus* is an extinct genus of the family Hominidae, and it is the most primitive man-like species known.

More recently in England, in ancient river deposits, remains of another extinct genus of the Hominidae known as *Eoanthropus*—the dawn man—has been discovered (Figure 91). The skeletal parts are quite incomplete (see Hrdlicka, '14; MacCurdy, '24) and some aspects of the reconstruction are questioned, but it is generally accepted that this fossil genus is intermediate in structure between *Pithecanthropus* and *Homo*. An age of several hundred thousand years may be assigned to the Dawn Man.

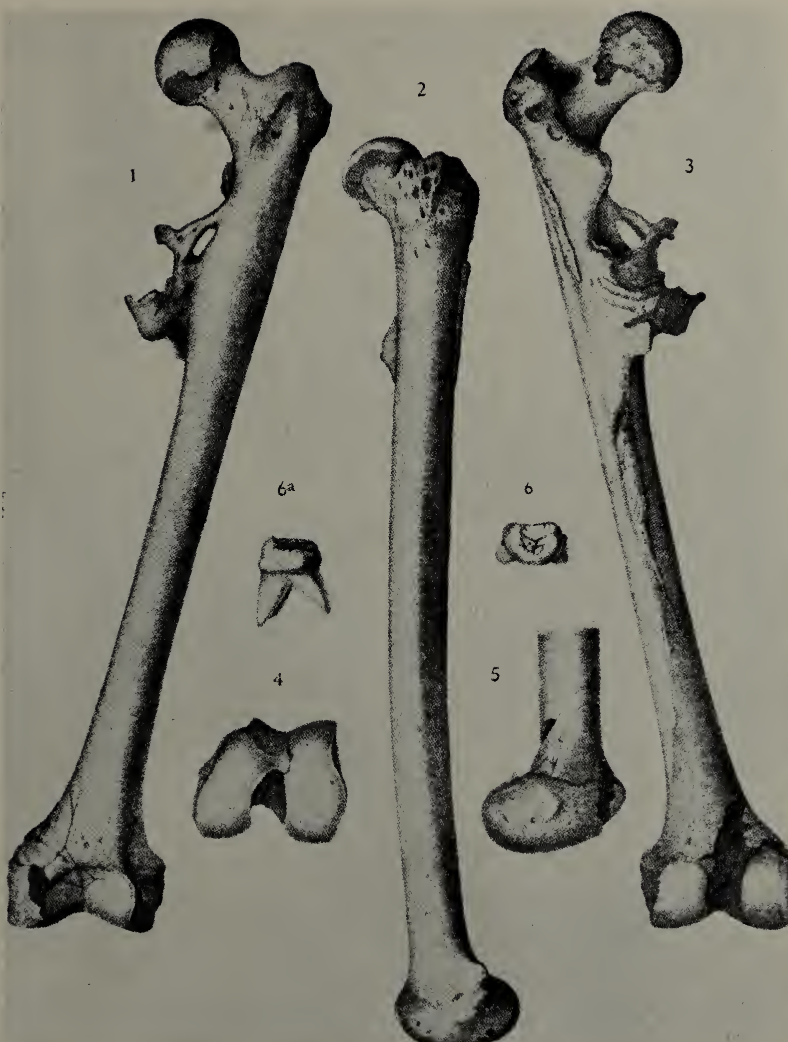

Fig. 87. *Pithecanthropus erectus.* Left femur: 1, from before; 2, from side; 3, from behind; 4, from below; 5, lower end from median side; 6, right third upper molar, from below; 6a, from behind. After Dubois.

Fig. 88. Restoration of the skull of *Pithecanthropus erectus*. Half the natural size. After Dubois.

Other earlier and later discoveries in western Europe have revealed, chiefly in cave deposits (Figure 89), the presence of several extinct species of the genus *Homo* to which modern man belongs (Figures 93-94). The species lived during the Paleolithic or Old Stone Age (Osborn, '15) and were acquainted with the Pleistocene cave-bear, the sabre-tooth, the mammoth, the woolly rhinoceros and the horse. These Paleolithic people left abundant evidences of their artistic abilities by paintings on the walls and roofs of the caverns they inhabited. Sculpture in clay was a part of their record, and these histories have been preserved over many thousands of years in caves whose inhabitants have perished in the long ago.

One of the most important and abundant records left by early man was his work in flint (MacCurdy, '24), either as tools or as weapons. The term *eolith* designates a crudely chipped flint which played a part in human history. Such flints are found in rocks of Tertiary age, and there is considerable doubt of these flints being hand-made. They were more probably made by frost or mechanical abrasion by erosion. Early man did, however, learn to make beautiful flints.

Fig. 89. Early man was long a cave dweller, when possible, and in the floor of this cave in southern England were found many evidences of a long residence by ancient man. Although there are many caves in Indiana, yet none has revealed evidences of man's presence at a period of more than 5,000 years ago. From Hrdlicka.

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Fig. 90. The La Chapelle-aux-Saints Skull. Side View. This skull was found in a burial, in the floor of a cave in France, and is thought to represent a very ancient race, possibly more than 100,000 years old. It is interesting to note that even in this early time the man had lost most of his teeth from pyorrhea. After Boule.

Gradually the Paleolithic, or Old Stone Age, died out and was replaced by the Neolithic, or New Stone Age, during which men perfected their tools and weapons, and built substantial houses, often for protection, as lake-dwellings. Men learned to till the soil and raise grain, to weave cloth and to make potteries. Yet always ancient man had to do battle with savage beasts, with equally savage men, with disease, with changing environments. It may have been during the closing centuries of the Neolithic that man aspired to erect huge stone monuments, "menhirs," weighing many tons, and to erect huge burial mounds, called "tumuli."

The use of stone tools was unsatisfactory to the humans following the Neolithic age. Stone implements were hard to make. It was difficult to sharpen them to a keen edge. They were heavy and broke easily, and thus was ushered in the Age of Bronze to be more quickly followed by the Iron Age.

It was possibly during the Neolithic that the crowding of populations brought about the impulse to wander, to migrate, to seek out new countries. Possibly some of these ancient races came to America and developed into the American Indian.

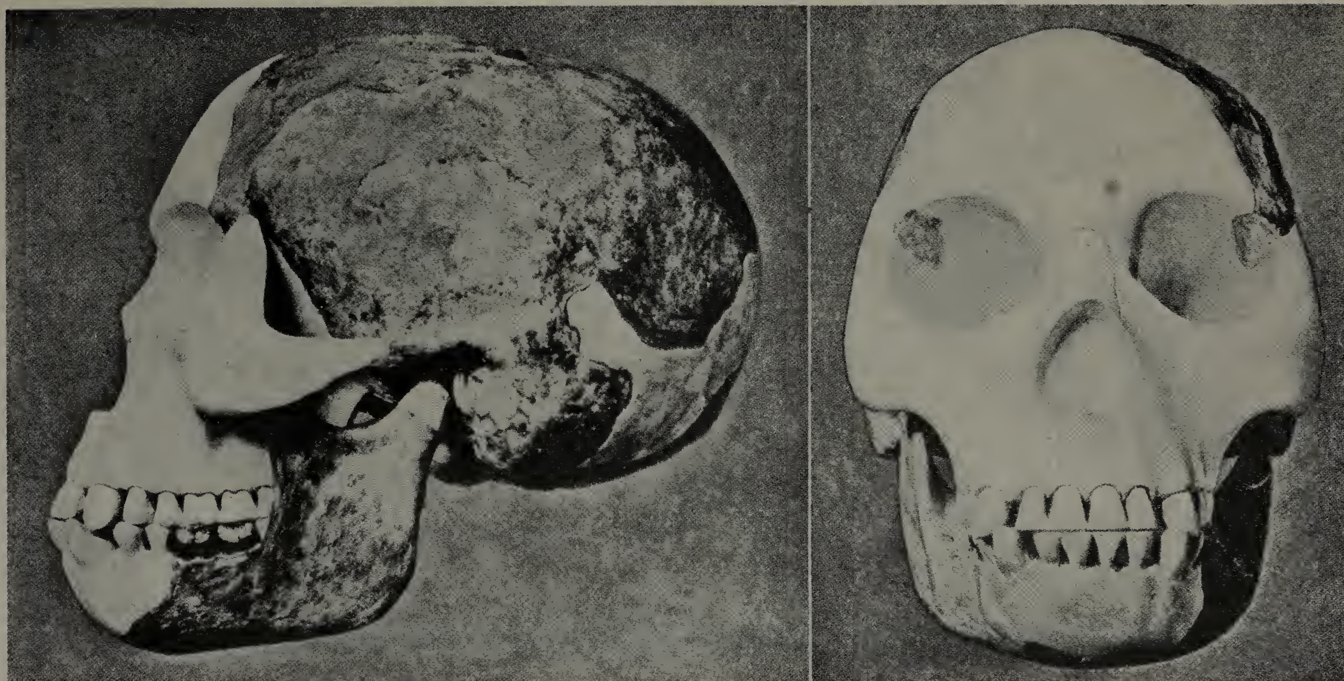

Fig. 91. First restoration of the Skull and Mandible of *Eoanthropus dawsoni*. After Dawson and Woodward.

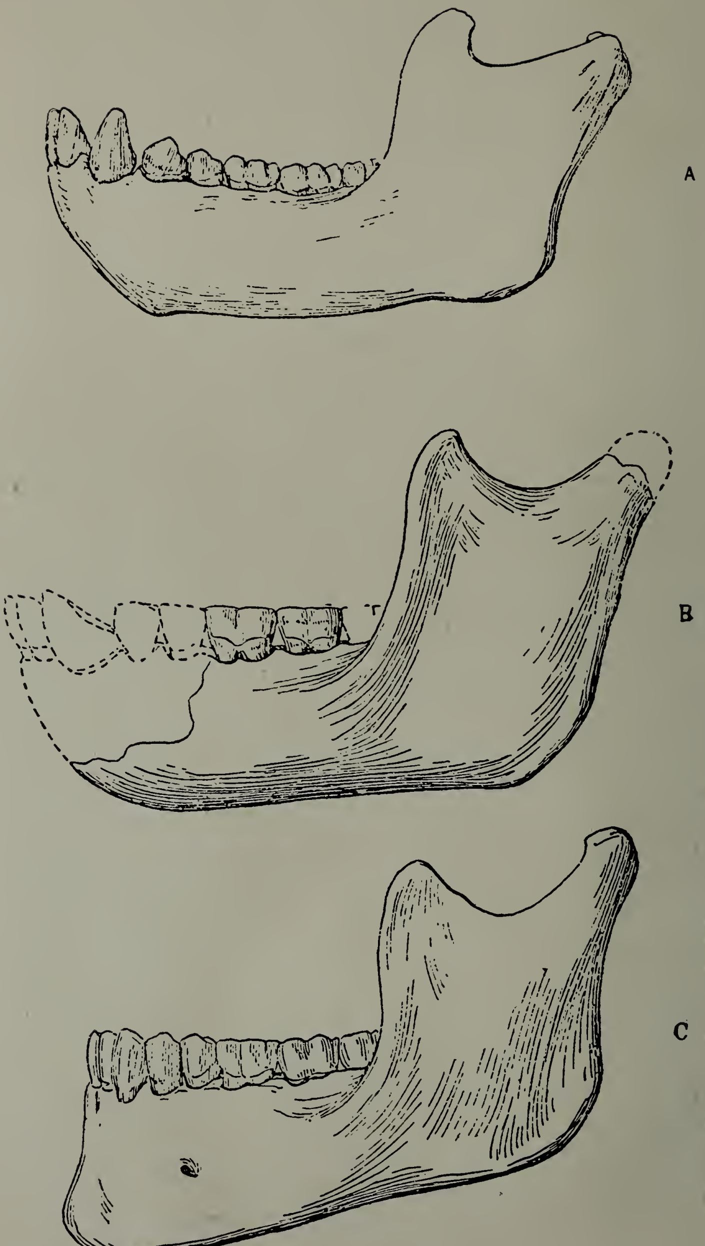

Fig. 92. Restoration of the Piltdown Mandible (B), compared with that of man (C) and young Chimpanzee (A), in left side view. After A. Smith Woodward.

Fig. 93. The Mauer Lower Jaw. After Schoetensack. About two-thirds natural size.

Fig. 94. The Neanderthal Skull. Side view. After Hrdlicka.

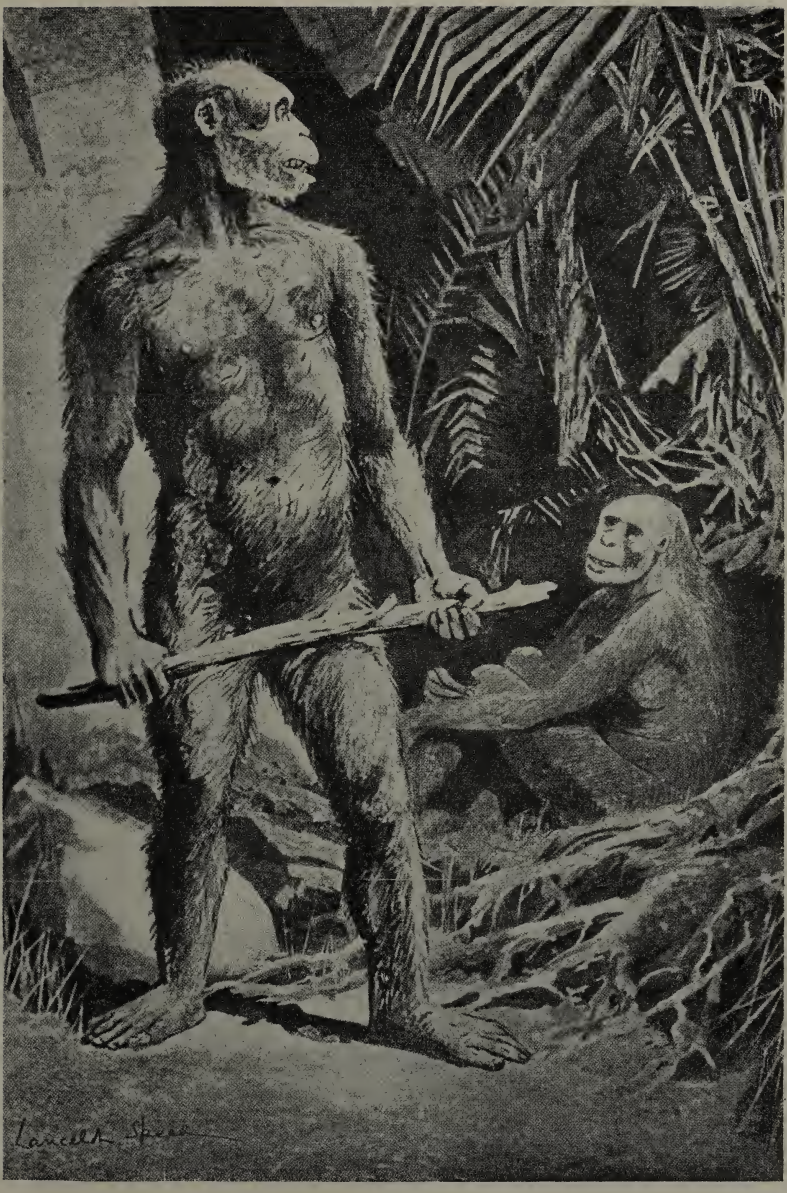

Fig. 95. Restoration of *Pithecanthropus* by L. Speed, from Knipe's *Nebula to Man.*

EARLY MAN IN INDIANA

It is well established that the human race has dwelt in the North American continent for a long time, probably for many thousand years. It seems probable that man entered the continent across the Siberian sea, passing from island to island over a long period of time, and then having attained the continent passed down along the Pacific Coast, and eastward across the plains areas into the eastern forests, thus reaching Indiana relatively late in history. It is not definitely known that man lived in America before the extinction of such Pleistocene mammals as the Mastodon (see papers by Balcom, Gorby and Taylor in Bibliography). MacCurdy* has reviewed the world-wide evidences for the origin of man, and Hrdlicka† has discussed the evidences for North America. More recently a number of writers, Gidley, Hay, Brown, Cook and others, have discussed the association of the remains of early man with the remains of Pleistocene mammals, but none of this bears directly on Indiana, so we may leave the discussion for future investigations.

The number of publications on the nature of primitive man and his evidences is enormous, and many pages could be filled with a list of papers, memoirs, books and reports, in many languages, describing the discoveries relating to early man. The following brief list will serve as a guide to those who desire to read further in this phase of Paleoanthropology.

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